POWER

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A Drop of Water

I am a drop of water.

For countless ages, yea, ever since the world began, I have been here to glorify my Creator and to serve and do the bidding of his servants, Mankind.

For years and years I have lain in the form of ice in the far frozen north, only to reak loose and roll into the sea, to wander for weeks until my form was changed (for I have many forms) back to a liquid, and I became a part of the sea.

Again and again I have been drawn from the sea into the clouds in the form of a vapor, carried far over the land and precipitated to the earth in the form of rain.

I have worn creases into the surface of the earth and washed the hilltops into the valleys; I traveled the Nile when Cleopatra was a girl, and many times since; out past Cairo into the Mediterranean and through Gibralter to the boundless ocean. Peaceful is the journey; but not so the times that I have been precipitated farther south where with a rush and a roar I have leaped for hundreds of feet over the Falls of Zambezi. Yea! and at Niagara I have been there and tempestuous was the passage. Over the brink to the water below, on to the swirling rapids, out into Ontario and the great St. Lawrence. Of late years they have placed forebays and penstocks and turbine wheels and tailstocks in my path there, and when I go that way, I turn the mighty electric generators that furnish light and power for the whole country side.

I have cooled the fever-parched lips of a little child and quenched the thirst of a dying soldier; the desert is turned into a place of beauty by my touch, and flowers and plants and trees grow at my bidding.

My power is without limit, yet when under control I am as docile as a kitten. If I am confined in a closed chamber and cooled, I will contract until I have reached a temperature of thirty-nine degrees, but if I am cooled below this point, I will expand again and if the cooling continues, woe be unto the vessel, for it must certainly break; again, if I am confined in a vessel and heated, I will expand and become a vapor. If the heating continues, woe be to the vessel again, for it must surely break. If the heating continues until I have reached a temperature of two-hundred and twenty-five degrees, I will have vaporized and expanded until it will take one thousand, two hundred and ninety-two times my original volume to make the same weight, and I will be pushing against every square inch of my container with a force of nineteen pounds.

I was in the kettle and bobbed the lid in trying to get out when James Watt discovered the great force that lay hidden in me, and I was there when he tried out his first machine for applying that force. Aye, and there was demonstrated that day an idea that was to be one of the greatest factors in the industrial development of the world.

Since that day men have used me more and more, and each year I have been subjected to higher temperatures until now when I enter a modern power plant, I am forced through a heater and heated boiling hot; thence through an economizer and into a large boiler, where I circulate inside of hot tubes, absorbing more and more heat, until I have attained a temperature of four hundred and four degrees and I am pushing out against the walls of my prison with a force of two hundred and sixty pounds per square inch; not satisfied with this, I am forced through a superheater on my way out, where I take on another hundred degrees.

By this time I am in the best condition to serve their purpose, and I am allowed to frisk out through a steam main and find my way, not to the cylinder of a steam engine such as Watt made, but to a mighty turbine.

With almost lightning speed I escape through a nozzle and strike a moving curved blade, only to be directed back against a stationary curved blade, where my direction is again changed and I impinge on another moving blade, gaining velocity each time until, twisting and turning, I scurry out through the last set of blading and into the condenser, where I am either met with a jet of cold water or strike against a cold tube and I find myself condensed back to water again. My mad rush is now over, and I flow out into the hotwell, and if I am lucky I escape through the overflow, back again to the river and once more to the free and open sea.

If I am not lucky enough to escape, I am drawn back through the intake and have to go through the same routine again, perhaps for days and weeks before I escape, but it makes no difference what you do to me, you cannot destroy me. You may boil me to a wild vapor, freeze me into ice, change me to a mist or a fog, or to hail, but always and ever I return again to my natural state to glorify my Creator, and to bless and do the bidding of his servants, MANKIND.

Contributed by Earl Pagett

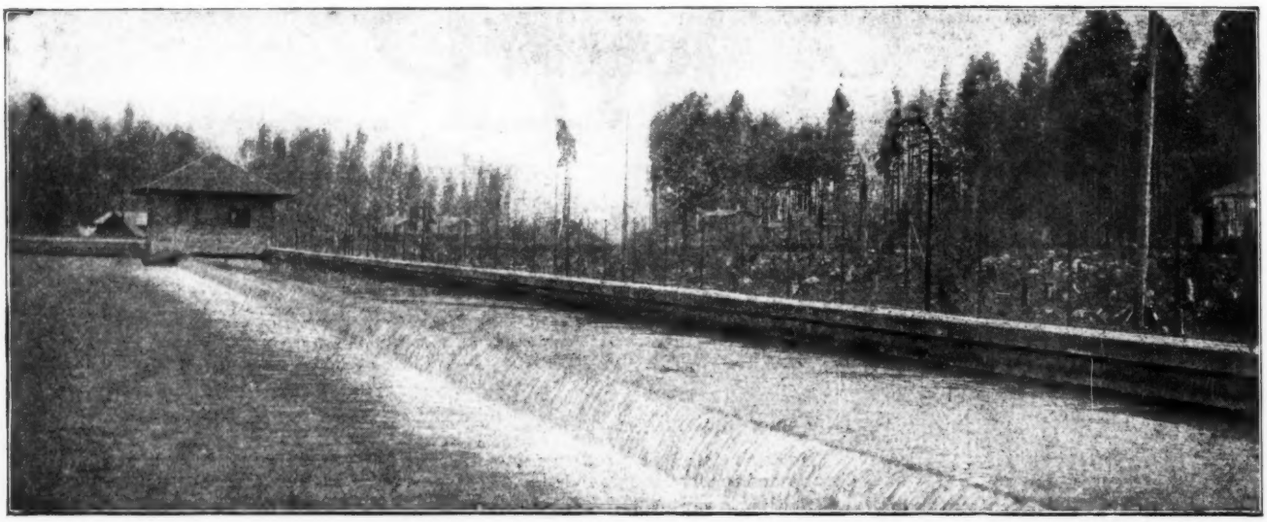

FIG. 1. THE WATER SLOWLY ENTERS THE RESERVOIR OVER A LEVEL WEIR 300 FT. LONG AND THUS DOES NOT STIR UP THE SILT

Silt Disposal at Tacoma Hydro-Electric Plant

By LLEWELLYN EVANS

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THE Tacoma Municipal water-power plant is located on the Nisqually River about thirty miles from the city. This stream has its source in a glacier on Mt. Tacoma (Mt. Rainier) and falls about three thousand feet in sixty miles and naturally carries quantities of silt during floods and considerable during the glacier melting period. The development consists of a 50-ft. concrete dam diverting the water across a bend in the river with a 10,000-ft. tunnel and thus gaining about 425 ft. of head. The plant depends on the stream flow and has practically no storage except such as can be had with flashboards on the dam during low stages of the river, amounting to about 60,000 kilowatt-hours.

This short and simple development is made possible by the wonderful natural condition at this point in the river, the stream having cut a canyon through a rock dike for about three miles, accumulating 425 ft. of fall in this short distance. The direct route across the bend by tunnel is still shorter. The steep banks made the penstocks less than eight hundred feet long.

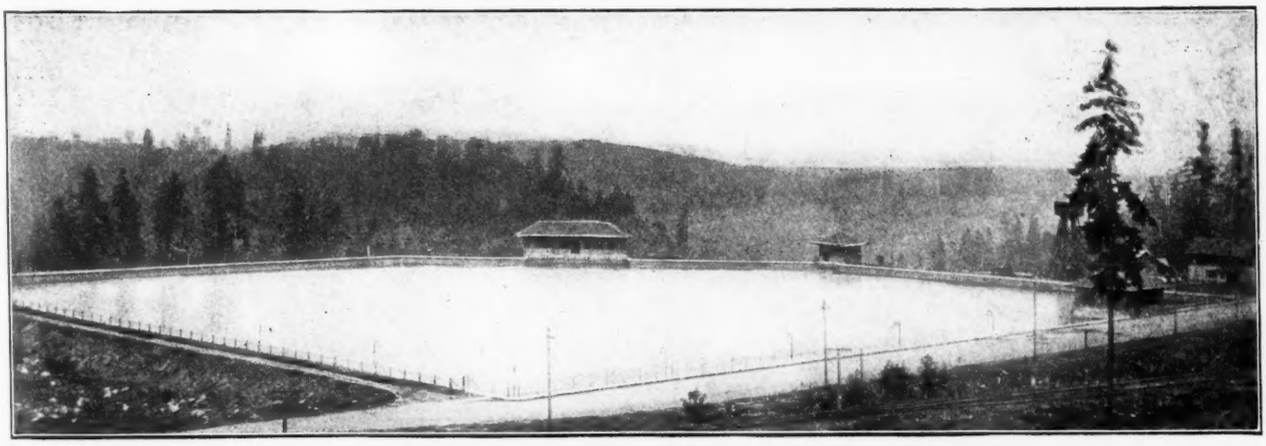
The silt condition was recognized from the first by the original engineers, of whom Frank C. Kelsey was chief, and provisions were made for handling the silt to the extent that its action could be foretold.

The intake was chosen at the inside of a bend about two hundred feet below a turn and directly behind the dam, as shown in the pictures. Screens with 4½-in. opening made of ½ x 6-in. bars are placed across five 10-ft. openings about 22 ft. deep. Immediately in front of the screens is a channel three feet or more deeper than the intake floor. This continues at considerable grade to the washout gates in the dam, the purpose being to keep the space in front of the screens clear of sand and débris with a high-velocity current flowing out through the lower gates. These gates also provide a means of washing out the river bed and the space behind the dam at certain low stages of the river. Behind the screens is a forebay, and then comes the three intake gates which control the water going to the plant. Between these gates and the entrance to the tunnel is a settling channel about eight hundred feet long and forty feet wide. This channel has a floor on a 1.8 per cent grade and at the lower end is about seven feet deeper than the entrance to the tunnel so that about seven feet of silt can be accumulated before any enters the tunnel. The canal is flushed by opening gates at the lower end and sending through sufficient water from the intake, the dirty water emptying below the dam.

The tunnel operates as an open conduit and is not under pressure. After leaving the tunnel the water crosses the river on a steel viaduct in a 10-ft. diameter closed pipe and proceeds underground in a short conduit and comes out into a regulating reservoir just above the plant, which is in the bottom of the canyon. The water enters this reservoir over a level weir about three hundred feet long and, if it were not for the entrance velocity, would be distributed over the reservoir with very little current, but because of this entrance velocity the water now piles up at the lower end of the entrance channel and goes over the weir with a gradually increasing depth, creating a direct current from the farther end of the weir to the forebay entrance. The reservoir is graded to one corner and provided with washout gates. There are bypass tunnels under the reservoir to feed the plant direct while the washout process is going on. A 75-hp. centrifugal pump providing water at 200 lb. pressure to the hose nozzles is used in flushing the floor of the reservoir. Once a year seems often enough to clean out. The accumulation is often seven feet high in places, but averages three or four feet at the end of the year.

The headworks washout gates and settling channel and reservoir have been effective in removing dangerous silt conditions up to about 50 per cent of load on the plant, about 400 sec.-ft. during floods. Beyond this load we have difficulties. The cutting effect of the silt shows up first in the reducing valves of the cooling water system, which are cut out rapidly. The piping for furnishing cooling water to the bearings becomes

clogged, and in fact we finally pulled out all the small piping and installed pipe of larger diameter. The turbine linings are soon badly cut, as shown in Fig. 6, and the backs of the runner vanes become deeply pitted. The cutting of the clearance rings of the runners causes the first trouble with the turbines, as they are single-discharge and the centering of the runner depends on the clearance on each side. The heating of the thrust bearing, which takes up side play in the runner, indicates the wear first. This extra pressure on the thrust bearing can be compensated up to certain limits by by-pass and drainage pipes and valves provided for this purpose. When the limits of compensation have been reached, the turbine must be taken down and all worn parts renewed. The pictures show what havoc can be done by the silt when it gets started. Five years' ordi-



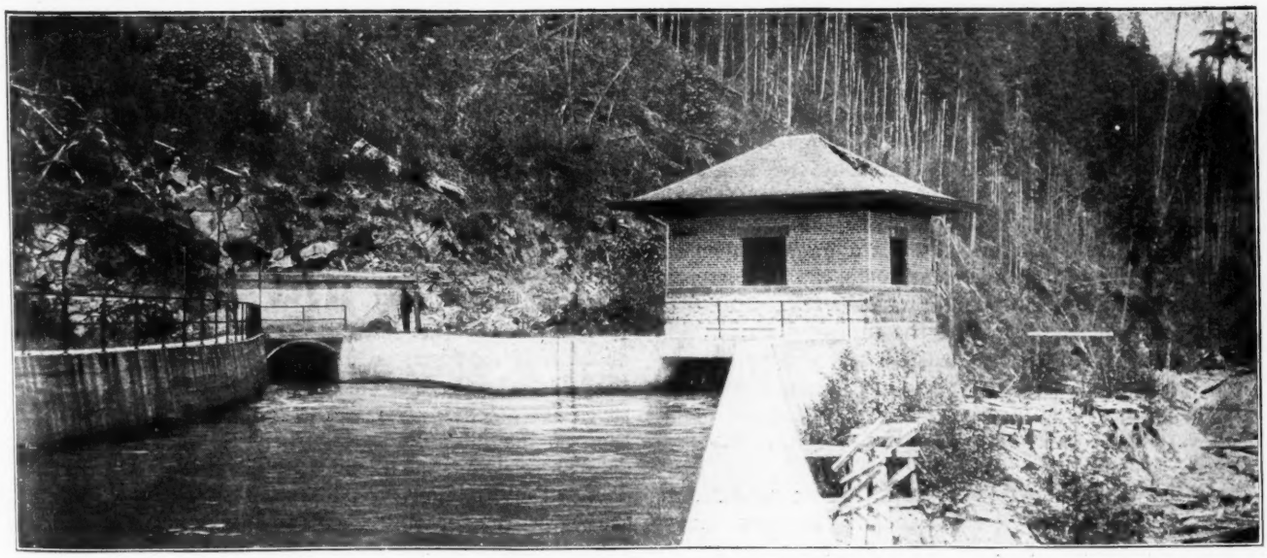


FIG. 2 (TOP). THE DIVERTING DAM ON THE NISQUALLY RIVER WHOSE SOURCE IS MOUNT RAINIER. THE INTAKE IS JUST TO THE LEFT OF THE TWO BUILDINGS ON THE RIGHT. FIG. 3 (MIDDLE). REGULATING RESERVOIR OF TACOMA'S NISQUALLY RIVER STATION. FIG. 4 (BOTTOM). PORTAL OF THE 10 000-FT. TUNNEL

nary wear with clean water or the milky glacier water causes no cutting to speak of, but one flood lasting three or four days while the plant was operating with full load, cut the liners, wickets and runners as shown in Figs. 5 and 6. The sharp, fine sand does all the damage. Apparently, the milky water of a glacier stream has no wearing effect. Our experiences in the flood of 1917 resulted in much study and experimenting, and as a result certain remedies have been applied with gratifying results.

The fundamental trouble has been at headworks where the washout gates, which should keep the intake screens open, have failed to function because they were too small to let through roots, stumps and logs which would not float. As long as these gates were open, the intake could be kept comparatively clear, but the minute the gates became choked, there was an eddy formed on the intake side of the stream, which furnished slack water where sand could settle and pile on top of the trash on the screens so as to immediately close the openings. In less than a minute after the gates become clogged, the intake is choked tight, and the only way to get any water to the plant is to put a gang of men to work raking the screens. As the roots, limbs, logs and leaves are scraped away from the bars, the sand will be freed and washed along into the intake. It soon fills up the settling channel, because the best a crew can do will not produce enough water to run the plant, making it difficult to get time to wash out the settling channel. So the water that gets through to the reservoir is heavy with silt.

This flood of 1917 was so unusual that no repetitions were expected for years to come and no extensive remedies were undertaken, and therefore there was a partial repetition of this trouble in 1918 and early in 1919. As during each flood we were faced with the absurdity of having an abundance of water in the stream and none for the plant, we considered several remedies, such as to provide an auxiliary intake or to move the present intake to a point upstream which was swept clear by high-velocity currents near the shore. As this was an expensive piece of work and still presented the possible difficulty of taking care of the new intake during flood, we finally decided on three changes:

1. To construct a drift barrier to catch all the drift approaching the intake.

2. To remove the fine screen at the intake and substitute a few heavy bars and to place the fine screen at the end of the settling channel where the rubbish could be taken care of by the settling-channel washout gates without the employment of a crew to clean the screens.

3. To distribute the water entering the reservoir over the weir more uniformly by installing flashboards of varying heights.

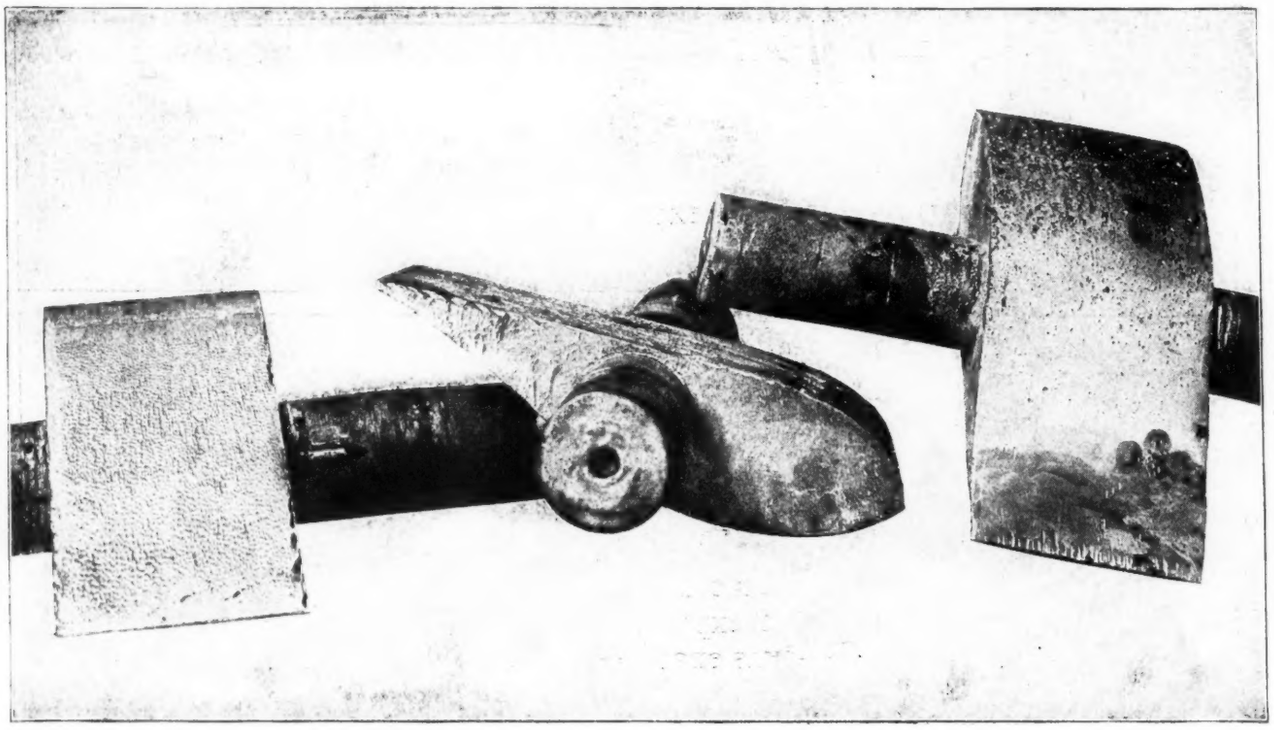


FIG. 5. WICKET GATES ERODED BY SILT. THESE GATES WHEN BADLY ERODED ARE COATED WITH STEEL BY WELDING AND THEN FACED

The dangerous material in the water during flood seems to be all sand. We have taken a series of samples at several stages of flood and found that the water appears clear in a test tube almost as soon as it can be held up and looked at after taking the sample. The sediment drops to the bottom of a 6-in. test tube, leaving a spot about the size of a thumbprint in the bottom. At the end of the settling channel the sample shows about half as much sediment, and at the entrance to the penstocks there is just a trace left. The sand particles are much smaller in the samples at the plant end than at the intake. Taking these samples aided us in determining how much load we could safely carry during flood without danger. We learned that we could improve the water by operating the three intake gates open, say, 2 ft., instead of one gate 6 ft. open, because of the amount of agitation caused in the settling channel. Furthermore, it was wise to avoid spasmodic changes

in the reservoir level because of the silt on the bottom which would be brought into suspension.

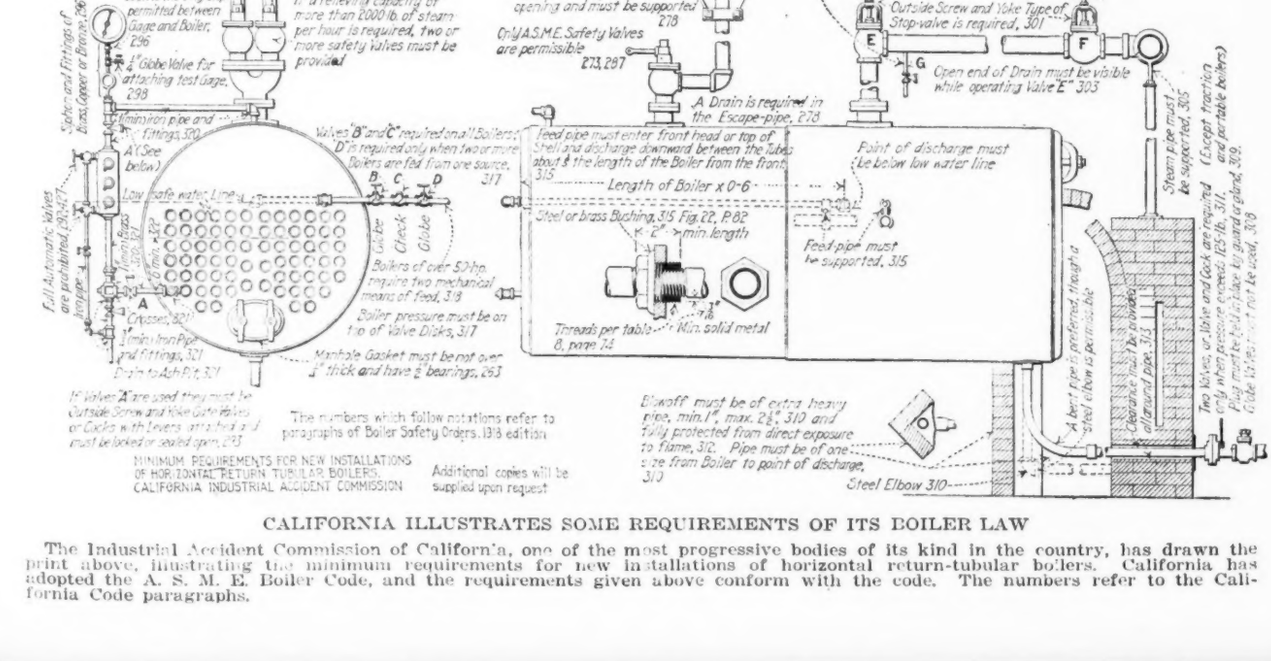
The drift barrier as planned for permanent use, will consist of steel cables one foot apart fixed between cement piers, like a wire fence, which will extend at right angles to the dam and be parallel with the stream lines of the natural river about thirty feet from the intake. We do not propose to stop all the drift in the river, but just that which tends to enter the intake. To insure sufficient water if the barrier should get clogged in a flood, we are making it about three hundred feet long so as to increase the area. It will extend upstream to a bend, where there is always deep water and high-velocity current near the shore to insure an open entrance to the space behind the barrier even if the barrier becomes closed down entirely next to the dam, directly in front of the intake.

Preliminary to building this structure, we have driven piling along the general route of the barrier in 10-ft. bents, and at the dam end we have filled in with piles about two feet apart. This temporary barrier and the change in the screens were put to test last December, when we had a severe freezing period which brought about four inches of ice on the back water behind the dam and broke up with a flood. The screens and barrier satisfactorily took care of floating ice as well as the sinking roots and trees.

The flood gates stayed open, and the screens at the end of the settling channel helped us get rid of the ice through the washout gates at the same time we washed out the silt. The ice in the river had formed jams and the river cut under them, stirring up the sand and making a dirty river, but the heaviest part of the sand went out through the sand gates in the dam and a wide area of the intake screen stayed open because the gates were clear. The velocity into the intake was reduced enough to settle out the worst of the sand. This flood did not reach so high a stage as the three former floods, but demonstrated that the work we had done was in the right direction and made us confident that we can ride out the worst kind of a flood.

These floods are not gentle affairs, but take on great force and tear up the landscape generally. We are not thinking of trying to control the whole stream, but will be thankful if we can handle the water we need.

FIG. 6. A. SILT-CUT SIDE FACING RINGS OF THE WICKET GATES; THE WICKETS HAVE BEEN REMOVED. B. THE BACKS OF THE BRONZE RUNNER VANES WERE MOST PITTED. C. WEAR OF THE SIDE CLEARANCE FACE OF THE RUNNER


Steam Gage must be graduated to 1½ times the pressure at which the Safety Valve is set, 297
If pressure exceeds 125 lb. all fittings must be extra heavy, 299-302
Escape Pipe must be at least full size of discharge opening and must be supported 278
Only A.S.M.E. Safety Valves are permissible 273, 287
A Stop Valve, "E" or "F" is required on each Steam-line, as near Boiler as is practicable; 301. If two or more Boilers are connected to a common pipe, Valves "E" and "F" are both required. "E" should be "non-return" and Drain "G" is required between the two Valves, 303
Outside Screw and Yoke Type of Stop-valve is required, 301
Open end of Drain must be visible while operating Valve "E" 303
Tee or Lever Handle Cock is the only stop permitted between Gage and Boiler, 296
If a relieving capacity of more than 2000 lb. of steam per hour is required, two or more safety valves must be provided
A Drain is required in the Escape-pipe, 278
Feed pipe must enter front head or top of Shell and discharge downward between the tubes about ⅓ the length of the Boiler from the front, 315
Length of Boiler x 0-6
Point of discharge must be below low water line
Steel or brass Bushing, 315 Fig. 22, P. 82
Feed-pipe must be supported, 315
Steam pipe must be supported, 305
(Except traction and portable boilers)
Low safe water Line
Boilers of over 50 hp. require two mechanical means of feed, 318
Boiler pressure must be on top of Valve Disks, 317
Manhole Gasket must be not over ⅛" thick and have 2" bearings, 263
Threads per table 8, page 74
Min. solid metal
Blow-off must be of extra heavy pipe, min. 1", max. 2½", 310 and fully protected from direct exposure to flame, 312. Pipe must be of one size from Boiler to point of discharge, 310
Steel Elbow 310
Clearance must be provided
Two Valves, or Valve and Cock are required only when pressure exceeds 125 lb., 311. Plug must be left in Tee to guard against dirt, 309. Globe Valve must not be used, 308
If Valves "A" are used they must be Outside Screw and Yoke Gate Valves or Cocks with Levers attached and must be locked or sealed open, 293
The numbers which follow notations refer to paragraphs of Boiler Safety Orders, 1918 edition
MINIMUM REQUIREMENTS FOR NEW INSTALLATIONS OF HORIZONTAL RETURN TUBULAR BOILERS. CALIFORNIA INDUSTRIAL ACCIDENT COMMISSION
Additional copies will be supplied upon request

CALIFORNIA ILLUSTRATES SOME REQUIREMENTS OF ITS BOILER LAW

The Industrial Accident Commission of California, one of the most progressive bodies of its kind in the country, has drawn the print above, illustrating the minimum requirements for new installations of horizontal return-tubular boilers. California has adopted the A. S. M. E. Boiler Code, and the requirements given above conform with the code. The numbers refer to the California Code paragraphs.

Vertical-Shaft Waterwheel-Driven Alternators—Mechanical Features

By S. H. MORTENSEN
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THE steady increase in the cost of coal has put a new valuation upon the energy from waterfalls and made its utilization one of national importance. This, combined with the improvements in power transmission, and the development of the efficient hydro-electric units for low and medium heads, makes it feasible to utilize waterfalls formerly considered of little commercial value. Practically all modern turbines for low and medium heads are of the vertical type, with the alternator directly connected. The success of this type of unit is mainly due to the relatively high rotating speed and high efficiency of the turbine, combined with the rigid and reliable construction of the vertical alternator. A modern unit of this type is shown in Fig. 1.

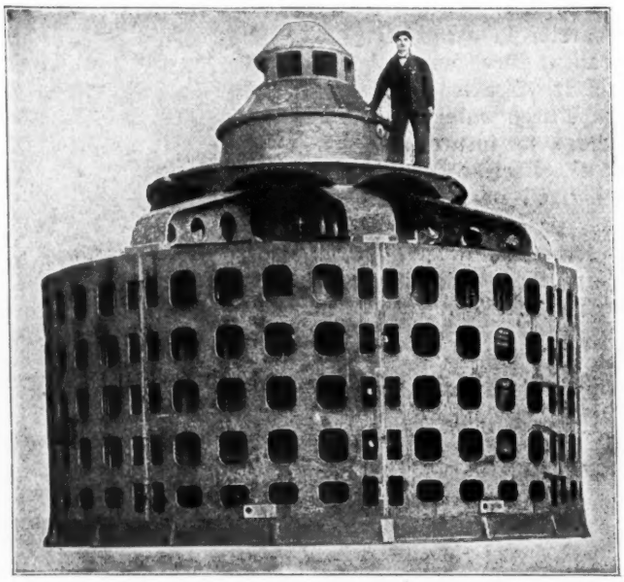


FIG. 1. ONE OF THE LARGEST HYDRO-ELECTRIC UNITS IN THE WORLD; 32,500-KVA. MACHINE

In the vertical alternator the electrical and magnetic features differ little from the well-known characteristics of the engine-type machine. Its mechanical construction, however, is different and requires special design for the stator yoke, bearing housings, bearings and oiling system. Furthermore, the characteristics of the hydraulic turbine make it necessary to embody a certain momentum, WR^2, in the alternator rotor, which also must have sufficient mechanical strength to withstand the centrifugal stresses corresponding to the runaway speed of the turbine. Experience has proven also the necessity of supplying the larger alternators with brakes to bring the rotor to rest. Finally, the proper ventilation and excitation of the vertical alternator leads to conditions that have a direct bearing upon its design. In a vertical machine the stator yoke supports the core iron and stator coils, and usually serves as a foundation for the step-bearing housing and thus supports the total weight of the rotating parts of the unit. The yoke consists of a stiff substantial casting made either in one piece or in several sections, depending upon the size of the machine, and is provided with uniformly spaced ribs into which the slots or dovetails holding the core punchings are cut. The yoke casting must have sufficient stiffness to withstand unbalanced magnetic pulls due to uneven air gaps or short-circuited turns in the field coils. Also, it must have sufficient mass and strength to support the upper bearing housing with its suspended load without undue deflection or vibrations. Furthermore, it should lend itself readily to the scheme of ventilation of the alternator.

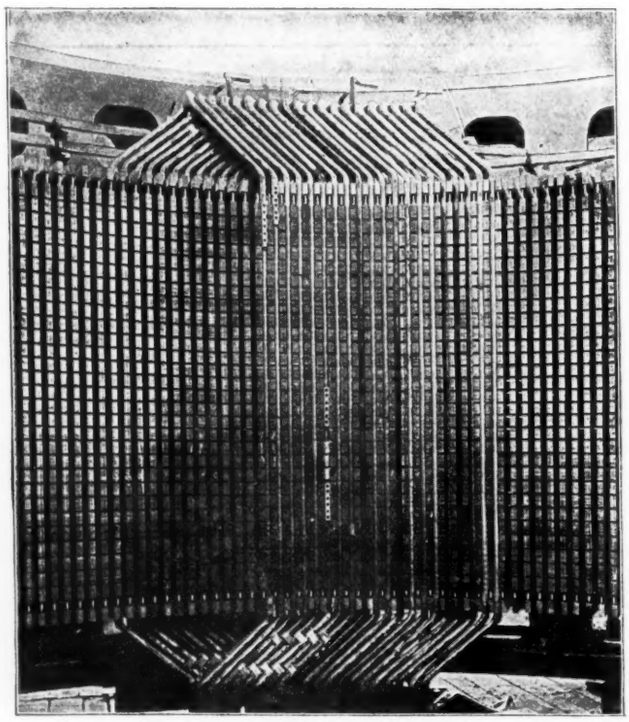


FIG. 2. SECTION OF YOKE WITH PUNCHINGS AND SOME OF THE COILS IN PLACE

A section of the yoke for the machine, Fig. 1, with the punchings and some of the stator coils in place, is shown in Fig. 2, and Fig. 3 shows a completely wound stator with the supporting ring for the stator coils. The supporting ring is necessary in large high-speed machines to prevent the movement or deformation of the coil end in case of short-circuits on the stator winding. The yoke is mounted on a base ring that may either be a separate casting or form an integral part of the hydraulic turbine. Adjusting screws, between the yoke casting and the base ring, provide means for radial adjustment. The base ring is bolted and grouted into the foundation and frequently serves as a support for the lower generator guide bearing

housing. On the top bearing structure are carried the thrust bearing and also the top guide bearing. This structure must have ample mechanical strength to support the weight of the revolving parts, together with the water column acting upon the turbine. Also it must have sufficient mass to eliminate vibrations that otherwise might result from the operation of the alternator. The top bearing structure may be either of the girder type shown in Fig. 4, or made with a number of arms like that on the machine, Fig. 1. To avoid circulating

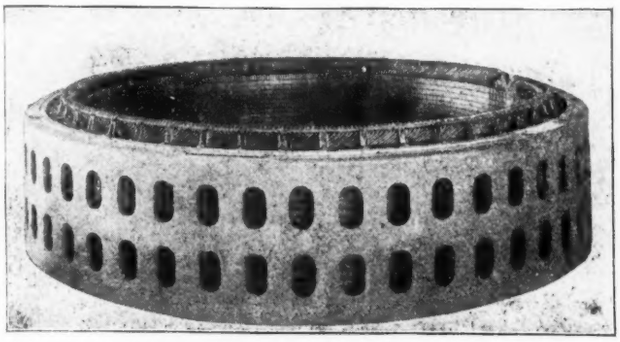


FIG. 3. COMPLETELY WOUND STATOR SHOWING RING SUPPORT OF COILS

currents through the bearings it is common practice to insulate the upper-bearing housing from the yoke. In units where the distance between the alternator and the turbine runner is large, the generator has an additional guide bearing whose housing may be supported from the foundation proper or from the base ring. The arms forming a part of the lower bearing housings are made of sufficient strength to support the weight of the rotating parts which, in case of repairs, can be elevated by means of jacks. The arms also form a convenient support for the brakes with which large machines usually are equipped.

The thrust bearing supports the rotating parts of the turbine and the alternator. Some years ago the accepted type was the pressure bearing mounted below the waterwheel. Oil was pumped under high pressure into a chamber between a revolving and a stationary disc, maintaining an oil film between the two surfaces. With this arrangement, the bearing was practically inaccessible, requiring a complicated high-pressure oiling

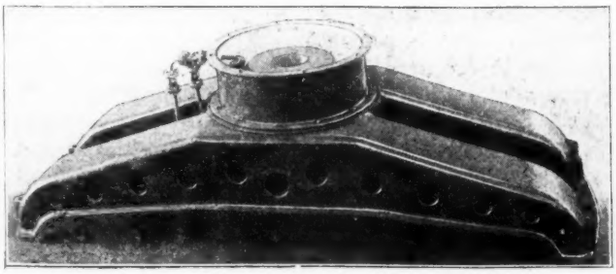


FIG. 4. TOP BEARING HOUSING, GIRDER TYPE

system. If, for any reason, the oil pressure dropped sufficiently to permit the plates to rub together, the result invariably was disastrous. This type of bearing has been replaced by the modern thrust bearing, which may be of several types. A roller-type bearing is shown in Fig. 5, the plate type in Fig. 6 and the Kingsbury type in Fig. 7. Either type of bearing may be mounted on the top of the upper bearing housing.

The roller thrust bearing shown in Fig. 5 was introduced several years ago and was used on several of the earlier installations. As may be seen from the figure, it consists of two steel plates hardened and ground, and a cage for holding the hardened and ground steel rolls that separate the plates. The rollers are made in short, straight sections. A bearing of this type has low fric-

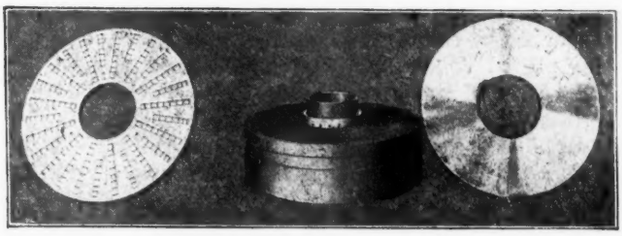


FIG. 5. ROLLER-TYPE THRUST BEARING

tion, but it requires exceptionally faultless material and also the highest class of workmanship. The bearing is mounted on a socket foundation that permits of a certain amount of self-adjustment.

The self-contained plate-type thrust bearing, Fig. 6, has the advantage of being simple in design and rigid in construction. It has only two wearing surfaces, which are cast-iron plates, made from a special close-grained iron, the surface being carefully machined and scraped. Radial oil grooves are provided to establish and maintain an oil film between the rotating and stationary bearing surfaces at all loads and speeds. The grooves in the rotating plate cause a thorough oil circulation and

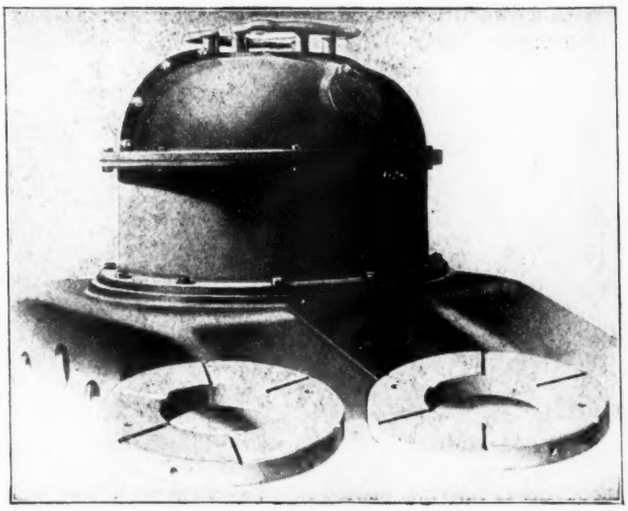


FIG. 6. PLATE-TYPE OF THRUST BEARING

spread continuously a fresh supply over the moving surfaces and prevent pockets of hot oil from forming. This bearing operates in a bath of oil in which a water-cooling coil is submerged, to carry off the heat generated by the bearing friction. With this arrangement, it is not necessary to circulate any oil through the thrust bearing. This type of bearing has been used for a number of small and medium-sized slow-speed machines. It is giving satisfactory service, particularly where the bearing pressures and rubbing speeds are moderate. A certain amount of adjustment in alignment is obtainable by means of adjusting screws bearing upon a collar.

The Kingsbury bearing, Figs. 7 and 8, represents one

of the most recent developments in the design of high-pressure thrust bearings. It consists of a flat annular revolving plate called the runner, which is supported on a number of babbitt-lined shoes mounted on pivots, permitting them to tilt sufficiently to establish a wedge-shaped oil film. Experiments have proven that a wedge-shaped film is very effective in automatic lubrication under high bearing pressures and speeds. The pressure upon the different shoes can be adjusted and equalized by means of screws, bearing upon the supporting pivots. The running surfaces are submerged in an oil bath and must be covered to a sufficient depth to prevent air from getting in between the rubbing surfaces of the bearing. Precaution must be taken to prevent the oil from churning and mixing in air bubbles, as this may cause the wiping of the babbitt on the bearing shoes. For medium and low pressures the runner disc is made from cast iron; for slow-speed high-pressure bearings, hardened steel or chilled iron is used. The shoes are constructed from cast iron lined with babbitt except for particularly high pressures, in which case bronze shoes are employed.

Bearing Pressures Determine Oil Used

Oil for a thrust bearing varies with the service. Heavy grades are used for high bearing pressures at low speed, and lighter oil gives good results for low and medium pressures on high-speed bearings. The coefficient of friction of a Kingsbury thrust bearing is very low, equaling 0.00009 times the square root of the bearing speed in revolutions per minute. This coefficient is based upon a bearing pressure of 350 lb. per square inch and an oil temperature of 40 deg. C. (104 deg. F.). With a variation in the bearing pressure, the coefficient also varies, being inversely proportional to the square

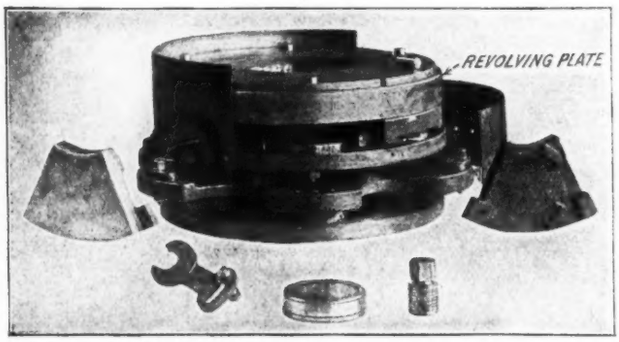


FIG. 7. KINGSBURY THRUST BEARING

root of the bearing pressure. This results in low bearing losses. For example, the losses in the thrust bearing shown in Fig. 1, are calculated to be 26 hp. when the machine operates at its normal speed of 150 r.p.m. As this machine has a rating of 32,500 kva., the thrust-bearing loss is less than 0.06 of 1 per cent.

In the operation of a Kingsbury thrust bearing the critical periods occur during the process of starting and stopping, when the surfaces of the runner and the shoes come into direct contact. This is due to the fact that in starting, the oil film is not established until a part of a revolution has been completed, and when stopping, the speed becomes too low to maintain the oil film. Only at these periods does perceptible wear occur on the bearing, and this also explains the noise that can be heard when a machine of this type is either started or stopped.

In the construction of a vertical waterwheel unit the number of guide bearings varies, but in all cases the generator has either one or two. In the installation, where the distance between the generator and the turbine runner is short, one guide bearing is supplied with the generator and one with the turbine. Where the distance is of considerable length, it is common practice to supply the generator with a lower guide bearing. It is general practice to make the guide bearings in sections to facilitate erection, inspection and repairs. The upper

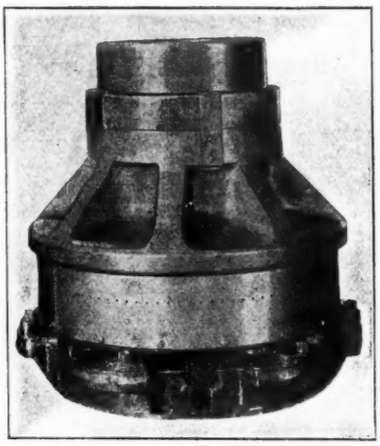


FIG. 8. KINGSBURY THRUST BEARING ASSEMBLED

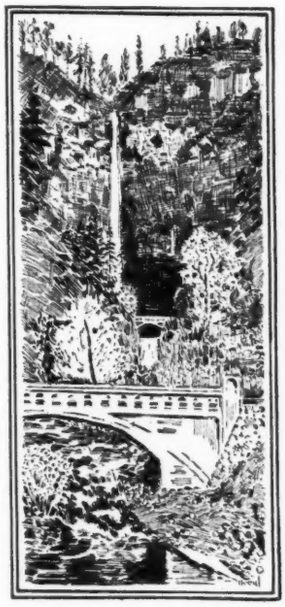
guide bearing fits solidly into a conical bearing seat in the top bearing housing and no provisions are made for any adjustment. The lower generator guide bearing is of the same general design as the upper bearing, but it is adjustable by means of setscrews. These bearings are made of sufficient size to resist pressures that may result from unbalanced magnetic pull or from other causes. The lower turbine guide bearing is mounted directly over the turbine runner. It is made from cast iron, lined either with babbitt or with lignum-vitæ. If a cast-iron babbitt-lined bearing is used, it is similar in construction to the generator guide bearings and requires a special oiling system. For that reason, the lignum-vitæ bearing is frequently preferred as it requires only water lubrication.

Modern lignum-vitæ guide-bearing design is based upon low bearing pressures per square inch of rubbing surface. The rubbing surface is made up from a number of lignum-vitæ strips equally distributed and dovetailed into the bearing box. The strips are mounted parallel to the axis of the machine and have the end grain of the wood normal to the bearing surface. The water for lubricating it passes through the bearing in grooves between the strips. It is essential that the water used for this purpose does not carry any foreign matter in suspension as this invariably leads to undue wear. Turbines operating in clear water have the lubricating water piped directly from the gear casing through a strainer to the bearing. If clear water is not available, a filter should be installed. No further piping is required, as the water escapes from the bearing to the draft tube through openings located in the hub of the runner.

Simplicity of lubrication is the main advantage of the lignum-vitæ guide bearing over the babbitt-lined type, as the latter requires a complete oiling system, together with a sealing ring to prevent its oil from escaping or getting mixed with water.

Power Problems of the Pacific Coast

By CHARLES H. BROMLEY



THE purpose of this article is to acquaint those not familiar with the Coast with some of its chief power problems and economic aspects. The Pacific Coast is a land where water is building an empire. To understand the country, its resources, its economics, its potentialities one must first understand its topography and climate, for these are fundamental in human pursuits there.

This is not the place for lengthy discussion of the interesting and remarkable features of topography and climate of the Coast, but a word about them is worth while here for those not familiar with them. The great body of the Pacific Ocean is warm, and as the prevailing winds are out of the west, the whole Coast country of the United States, from Puget Sound south to Mexico, is remarkably free from freezing temperature and snow. In the Northwest rain falls steadily, though not heavily, during many weeks of the winter. For nine months of the year most of California is practically free from rain. In most of California and all of the Northwest the mean temperature in summer is low. Most persons are familiar with the mountain ranges of the Coast. In this respect the Pacific Coast differs greatly from the Atlantic, in that it has no coastal plain.

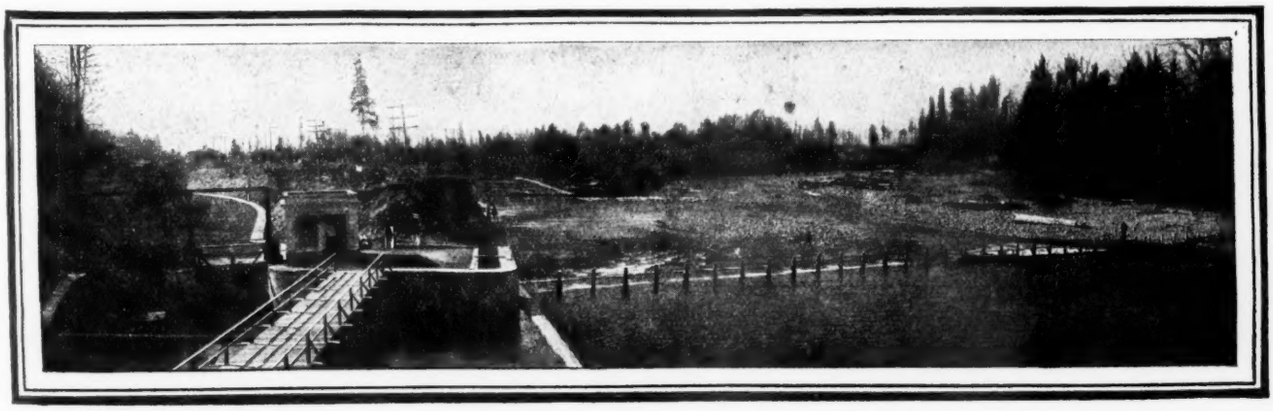
The warmth of the climate during winter, the abundant water power and lack of cheap fuels in adequate quantity make the Pacific Coast country almost ideal for the generation and transmission of power by large systems. Winter heating loads in business centers of towns and cities are excellently taken care of by district steam-heating plants, usually operated by the public-utility companies furnishing electrical energy, though sometimes by other independent companies.

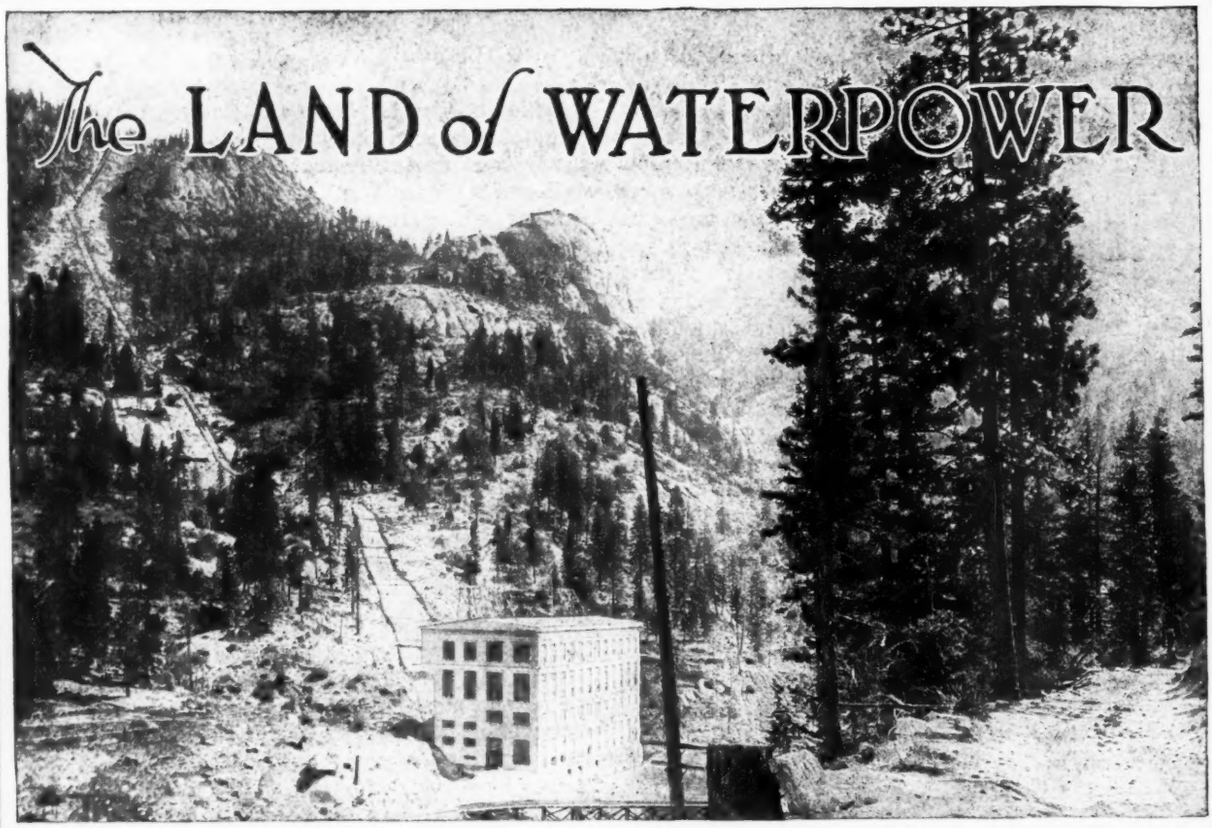
The basic sources of electric energy on the Coast are the high mountains, the Cascades in the Northwest and the Sierra Nevadas down the Coast. In winter these mountains become heavy with snow and glaciers which slowly melt during summer, and the run-off, together with rains, by aid of storage systems, supplies the streams which furnish hydro-electric power. Owing to the high heads available for hydro-electric plants, a little water goes a long way out there, measured in terms of kilowatts. To the man accustomed to great, wide streams and low-head plants, the little streams of the West, winding their way among steep-sided canyons, the power houses shooting small swift streams from their turbines, like water from a hose, present an interesting sight and more than interesting engineering problems. In California, particularly, most of these power houses are many miles remote from business centers and current transmission distances to points of consumption are great. But despite distances, the visiting engineer will miss a treat indeed if he doesn't get out to one or two developments. Views of Snoqualmie Falls and other plants of the Puget Sound Traction, Light and Power Co. are shown in Figs. 8, 9, 10, 11 and 12.

The Coast, particularly California, this season faces one of the most, if not the most, serious power and water shortages in its history. The Fates have been unkind in this land where water is life itself. The High Sierras have not their usual heavy coat of snow, which shines so prettily in the sky as one passes down the wide valley of the San Joaquin.

The major problem confronting engineers at this time is, of course, power shortage. But that is a manifold problem, and perhaps the most vexing of its components is the fuel problem. Fuel oil is the backbone of Pacific-coast steam stations. It is of California origin and, up until comparatively recently, has been available at a low price—much under a dollar a barrel. Now its price is so high that one frequently hears "prohibitive" used when it is spoken of. Every effort is being made to find other fuels, and this is as true of Los Angeles on the south as of Seattle on the north. In the Northwest hog-fuel, the refuse from sawmills, is being widely used and markets for it are being developed. Particulars are given elsewhere in this issue in an article devoted exclusively to the subject.

Farther south, in California, the San Joaquin Light and Power Co., with headquarters at Fresno, is developing considerable capacity in steam stations located in the oil fields where natural gas is available. At that





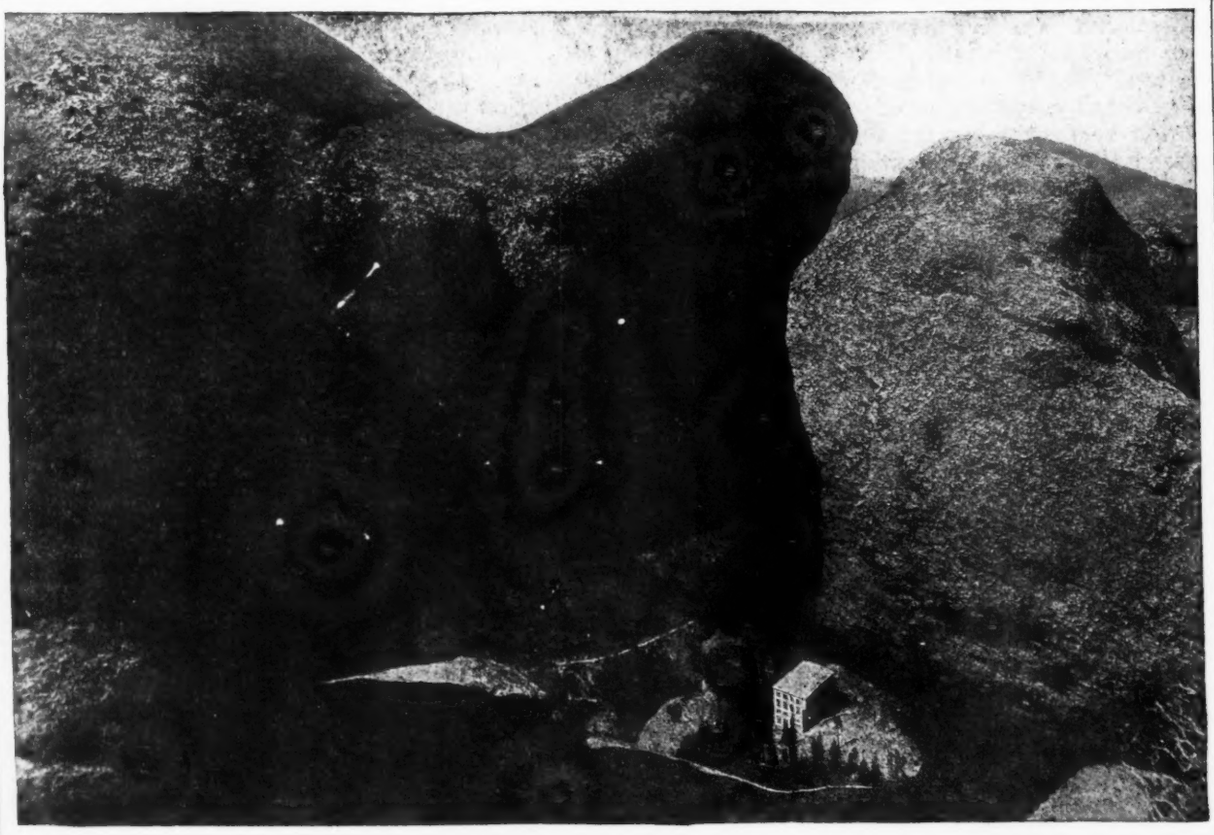


FIG. 1. UPPER VIEW. BIG CREEK POWER HOUSE NO. 1. SOUTHERN CALIFORNIA EDISON COMPANY. FIG. 2. LOWER VIEW. BIG CREEK SEEN FROM THE ROCK ATOP KERCKHOFF DOME

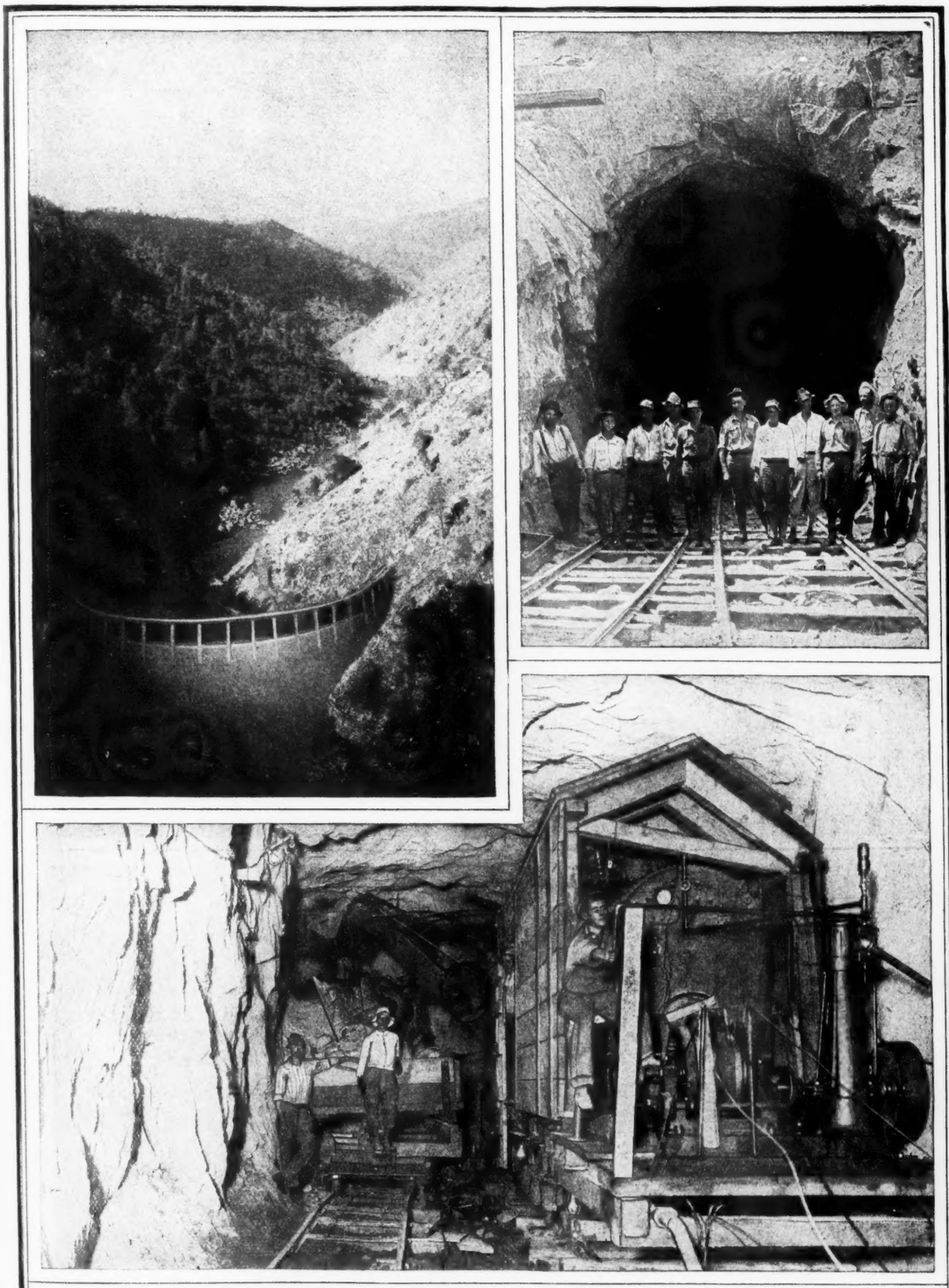
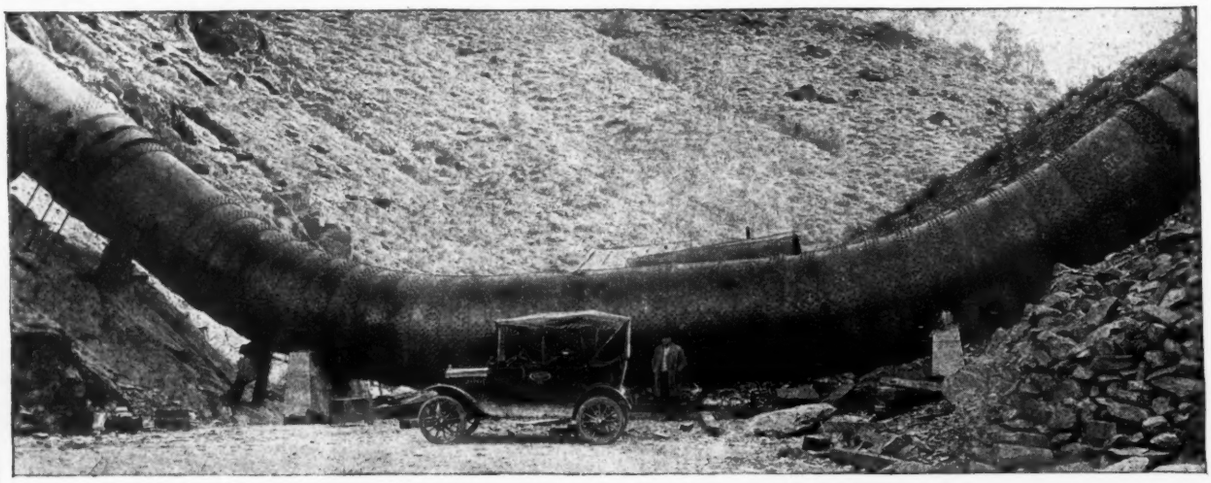


FIG. 3. TOP LEFT. KERCKHOFF DAM JUST COMPLETED, 100 FT. HIGH, 400 FT. LONG, SAN JOAQUIN LIGHT AND POWER CO. FIG. 4. TOP RIGHT. TUNNEL OPENING AND CREW, KERCKHOFF DEVELOPMENT. FIG. 5. BOTTOM. STEAM SHOVEL, AIR-DRIVEN, MUCKING OUT ROCK IN THE TUNNEL; PROGRESS, 12 FT. A DAY. DUMP CARS ELECTRICALLY OPERATED



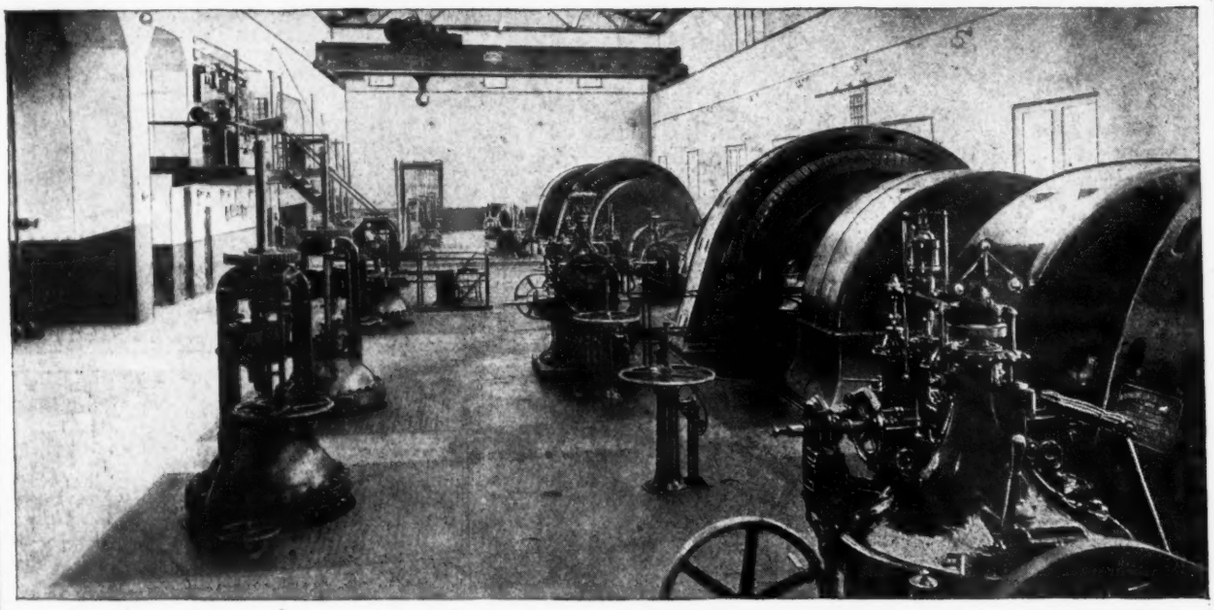


FIG. 6. UPPER. SIPHON, KERN RIVER NO. 3, SOUTHERN CALIFORNIA EDISON CO., TYPICAL OF COAST HYDRO-ELECTRIC DEVELOPMENTS. FIG. 7. MIDDLE. INTERIOR KERN RIVER NO. 1. FIG. 8. LOWER. SNOQUALMIE RIVER JUST ABOVE THE FALLS, PUGET SOUND TRACTION, LIGHT AND POWER CO., SEATTLE

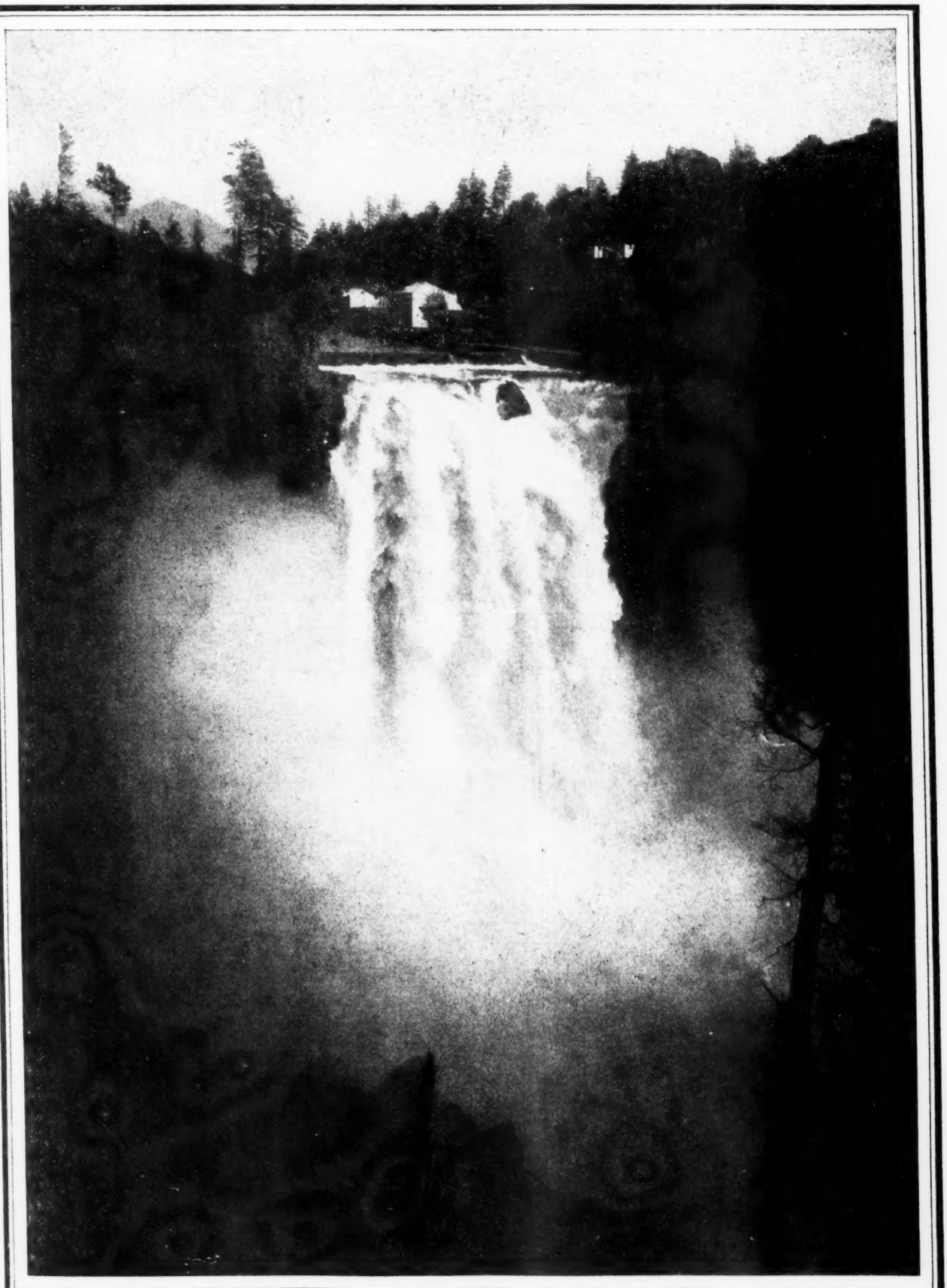
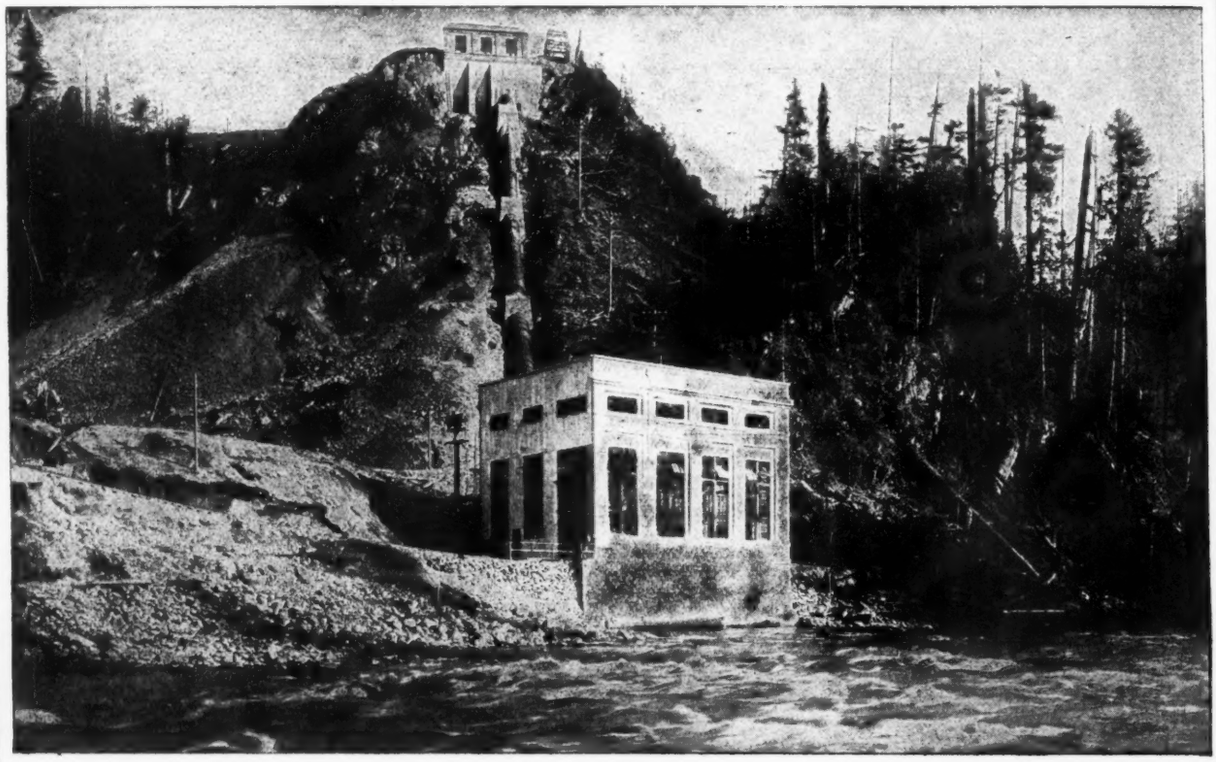
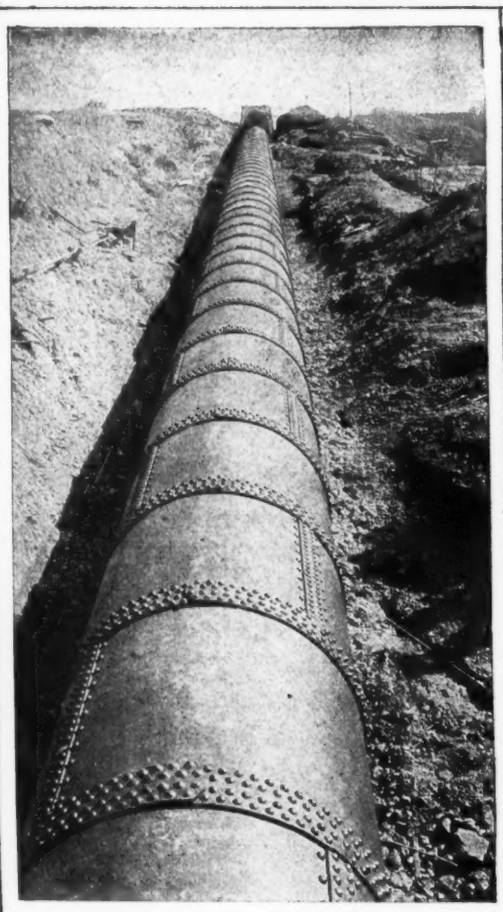


FIG. 9. BEAUTIFUL SNOQUALMIE FALLS, SEATTLE

The intake descends 270 ft. to the power house located in a cavern. The first hydro-electric development in the Far Northwest.





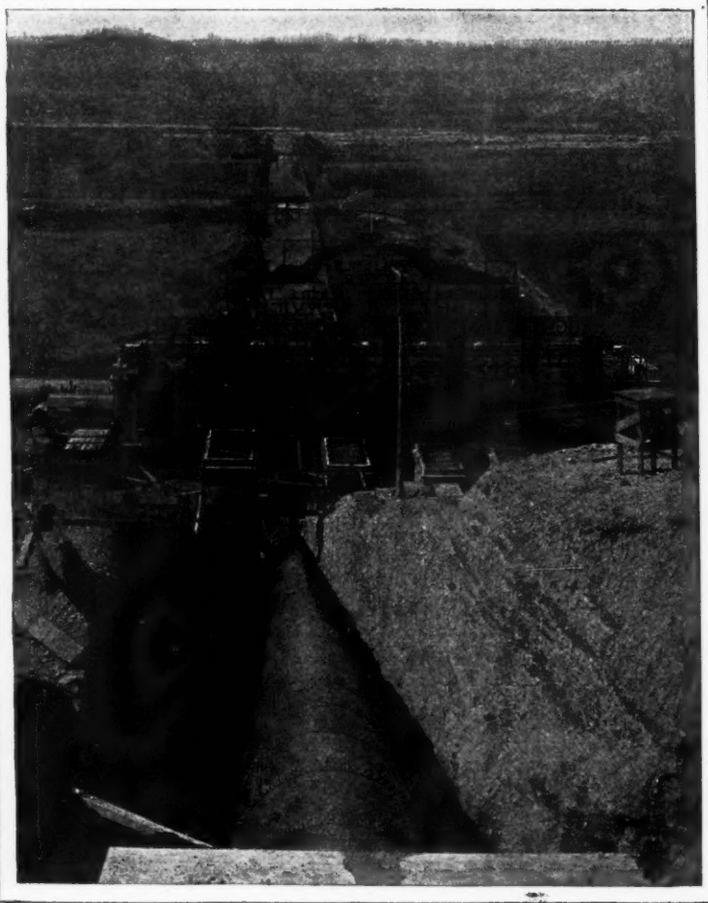


FIG. 10. UPPER. NO. 2 UNIT, SNOQUALMIE FALLS, PUGET SOUND TRACTION, LIGHT AND POWER CO., SEATTLE. IG. 11. LOWER LEFT. HEAVY CONDUIT TO THE PLANT ON THE RIGHT. FIG. 12. LOWER RIGHT. ANOTHER PLANT OF THE PUGET SOUND TRACTION, LIGHT AND POWER CO.

company's Bakersfield plant, recently enlarged by 15,000 kw. with another unit of similar size to come, gas is burned. But it is pumped a considerable distance before reaching the plant. There is now discussion of locating another large steam station in the very heart of the gas field where the point at which it is collected will be adjacent to the station. The oil industry itself will likely take considerable of the output of such a station.

Steam-station development in this gas area would seem a logical and profitable one in view of the urgent pleas to interconnect the transmission systems of California. Time seems to be showing that a greater proportion of steam-electric generating capacity is required. While the Railroad Commission of California reports that 75 per cent of the 2,892,000,000 kw.-hr. generated during the year 1918-19 by the public utilities of the state was generated from water power, this percentage is not true of some of the larger companies. This is the fourth consecutive year that one large company at least has furnished approximately 60 per cent of its output by steam stations and 40 per cent by hydro-electric stations.

The Coast has never attempted the wide use of Western coal. With fuel oil so high in price, serious attention is now being given to this. The Puget Sound Traction, Light and Power Co. is now getting satisfactory results with a lignite culm which it is using in pulverized form in its Western Avenue steam-heating station, Seattle, Wash. The performance has been highly satisfactory. The steadily rising price of oil causes a trend which gives coal an increasingly better chance in the power fuel market. So long as steam stations on the Coast continue to be used for purely emergency service, Western coal is not likely to find a large market in these power stations. But there are possibilities that with further expansion of the electrical industry it may be found at least expedient to design and build more large steam plants intended for more or less continuous service at high efficiency. Perhaps the most modern steam plant on the Coast is Station A of the Pacific Gas and Electric Co., San Francisco.

Interconnection which will tie in all the transmission systems of the Coast is one of the big dreams. And it may eventually turn out to be one worth while exploiting. California is fairly well tied together now, though not as completely as it may soon be. The central and northern parts of the state long ago standardized on 60-cycle current, but a part of the southern end is given over in large measure to 50-cycle current. This condition is being corrected. One of the features in this work is interesting. The new Kern River Station No. 3 of the Southern California Edison Co. has capacity of 22,000 kw. in two reaction hydraulic turbines working under 800 ft. head. Much of the company's system is of 50-cycle frequency, while the systems with which it is desirable at times to tie in are of 60-cycle. The engineers of this company, and the builders of the turbines, the Pelton Water Wheel Co., of San Francisco, have arranged to furnish both 50-and 60-cycle current with these machines. Each machine has two runners, but of course only one at a time is used. One will give a speed of 500 r.p.m. and 50 cycles at this speed, the other 600 r.p.m. and 60 cycles. The design is such that either runner may be taken out, loaded on a truck, pulled to one side and the other runner, which rests on a truck in a bay, rolled under the turbine and slipped on the shaft. The builders are confident that when the men become accustomed to making the change-over they will easily do it in eighteen hours. This is one of the things the Southern California Edison Co. is doing to adapt itself to the 60-cycle standard, and surely it is a clever idea. A part of a siphon used on Kern River No. 3 is shown in Fig. 6. Views of Big Creek No. 1 are shown in Figs. 1 and 2.

In the hydro-electric developments of the Coast, particularly California, considerable tunneling is necessary in conduit construction. And these tunnels are invariably through granite, of which the Sierra Nevadas are formed. In Kern River No. 3 development, just referred to, there are 60,000 ft. of tunnels, the longest being 7,132 ft. Recently the San Joaquin Light and Power Co. kindly took the writer from Fresno to its great Kerckhoff development up in the mountains along the San Joaquin River (see Fig. 3). This is the largest hydro-electric job under construction in California at present, and the method of driving the tunnels is one of the interesting features of the construction work. Figs. 4 and 5, page 703, show two views of one of

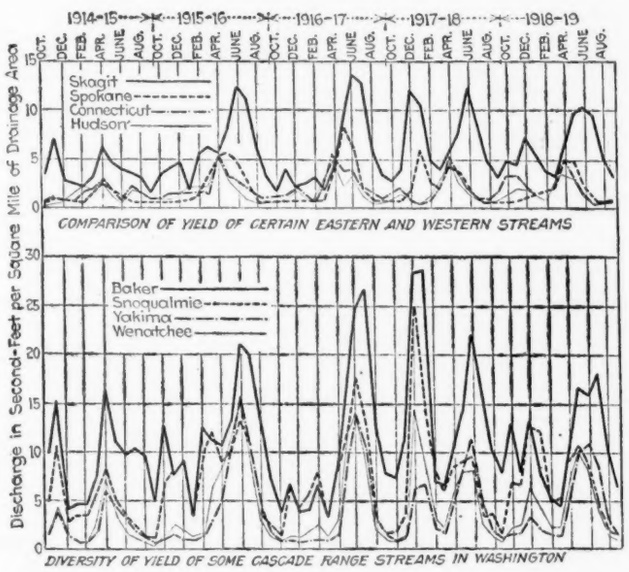


FIG. 13. FLOW CURVES COMPARING SOME WESTERN AND EASTERN RIVERS

the tunnels. This tunnel is 17 ft. diameter. The men are up ahead of the steam shovel preparing the rock for blasting. When the rock is shot out, the shovel, which is driven by compressed air to avoid smoke, is used to "muck out" the broken rock and load it into cars, which are hauled by an electric engine. How well this method is applied here may be judged from the fact that the average daily drive into the mountain is twelve feet. Unlike the tunnels of the Kern River No. 3 development, this one will not be finished with concrete, the rock surface being left free of covering of any kind. See Fig. 7 for interior of Kern River No. 1.

Power recently made editorial mention of the need of funds for gathering further data on the flow of rivers on the Pacific Coast. The purpose of here reiterating it is to give it emphasis. Accurate knowledge of stream flow is essentially vital to stable hydro-electric development. No one but the district engineers of the Geological Survey in the Northwest particularly knows what it has meant to the routine of these district offices

to get essential stream flow data during the trying years of the war when these offices were shorthanded. Such data were gathered regardless of what else had to be dropped, and for this the district engineers deserve credit. But surveys of broader and deeper character are desirable, and these cannot be made without a material increase in funds. Few Easterners appreciate the volume and uniformity of flow of many rivers of the Northwest. Unfortunately, we have but few flow curves, but some are shown in Fig. 13.

In this all too general and brief perspective that the writer has here given, the famous Hetch Hetchy project of the City and County of San Francisco deserves conspicuous place, for it is one of the foremost engineering problems of the Pacific Coast. Hetch Hetchy's power plants are in a measure incidental to the main purpose, which is water supply. For the greater part of the work high praise is due M. M. O'Shaughnessy, chief engineer of the City and County of San Francisco. The Hetch Hetchy site consists of 420,000 acres at the head of the Tuolumne River about 160 miles from the city. Ultimately, it will furnish 400 million gallons daily and develop about 250,000 hp. by reason of the waters' fall toward the city. A power plant of 4,400 hp. was built to furnish current for construction. Up to July, 1919, $7,516,000 had been spent on the project. The sale of surplus power from the construction power house alone netted the city $80,000 in twelve months. So far the city has done most of the work itself by day labor.

The first large power unit in the line of the aqueduct will be the Moccasin Creek power house, which will have capacity for immediate delivery of 66,000 hp. The city engineer points out that the present yearly consumption of electricity by the city is 360,000,000 kw.-hr. and that when the aforementioned power house goes into service the current available to the city will be about double that consumed now. In reaching the city the waters from the project will drop 8,000 and 10,000 ft.

A Super-Power Plant for Paris

A rather striking boiler plant was described by Harold Goodwin, Jr., of the Power and Mining Engineering Division of the General Electric Co., in an address before the American Institute of Electrical Engineers, Washington Section, on April 13. Mr. Goodwin discussed the procedure of his company in designing the layout and equipment for a super-power plant, which it is proposed to build for the City of Paris. This plant is designed to consist of seven steam-turbine generators of 35,000-kw. capacity each, the plan being to have this new plant supersede all existing plants in the City of Paris.

The boiler plant is arranged with four boilers of a novel type to supply each turbine. These boilers are to have two banks of tubes, a set of superheater coils being installed between the upper and the lower banks. This arrangement was deemed necessary because it is intended to operate the plant with steam at 325 lb. and 320 deg. F. superheat at the turbine. The boilers will, therefore, operate at approximately 750 deg. F. and 350 lb. pressure. With such steam conditions, it is believed impracticable to use pumps or other auxiliary equipment direct on boiler-pressure steam, therefore all the auxiliaries and the station light and power are to be supplied through small auxiliary turbines, one of which is installed for each pair of the main units. Unusual precautions are taken to insure continuity of operation to the auxiliary equipment, especially that of the boiler room, including stokers, feed pumps, etc.

Because of the large capacity of each of the turbines a double steam main from each group of boilers is provided.

Coal can be received either by boat on the Seine River or by railroad car. When coming by boat it is unloaded by cranes and delivered either into stockpiles or to the track hoppers, from which it is conveyed to the crushing stations. When delivered by railroad cars, it is dumped directly from the car into the track hoppers. From the crushing station the coal can be carried either to the bunkers, of which there are three, or to stockpiles. Storage space is also provided for uncrushed coal, so that the maximum of flexibility in handling is attained. Recovery from stock, either crushed or lump, is accomplished by grab buckets on locomotive cranes or the traveling crane, which swings about from each bunker. The crushed coal is conveyed from the bunkers to the boiler room by larries traveling on overhead tracks that intercommunicate throughout the system. The larries dump the coal in the small hoppers that feed the stokers.

It is estimated that the plant, as designed, would have cost approximately $45 per kilowatt of capacity on the basis of pre-war conditions. The exact present cost has not been calculated, but it is believed that it will lie between two and three times the pre-war figure, probably nearer three times. As a result of the unfavorable conditions of international exchange, much of the boiler and plant equipment will be built abroad, although considerable of the electrical equipment will be constructed in this country. Since no final estimate as to the power required for all of the auxiliaries has yet been completed, the over-all efficiency of the plant has not been estimated, but it is believed that not more than ten pounds of water will be required per kilowatt-hour. With the normal power for auxiliaries this would require approximately 1¼ lb. of coal per kilowatt-hour, judged under American conditions of fuel supply.

A power plant whose four units were designed to develop a total of 144,000 hp. would make a fair-sized central station. The main driving units of the British battle cruiser "Hood" were built to produce this amount and on the trial trip actually developed a total of 157,000 hp. The high-pressure turbines make 1,500 r.p.m. and the low-pressure turbines 1,100 r.p.m. at full power. The propellers are driven at 210 r.p.m. through single reducing gears. Steam is supplied by twenty-four Yarrow type small tube boilers having a total heating surface of practically 175,000 sq.ft. and a working pressure of 235 lb. per sq.in. The pressure at the turbine governor is 210 lb. per sq.in. and a vacuum of 28 in. is maintained in the condensers.

Utilization of tidal ebb and flow is gaining a foothold in Great Britain. The principle underlying the inventions for harnessing the tides is the working of a turbine by the inflow and outflow of the tides. One plan advanced calls for the building of a wall extending out into the sea or river in which turbines are placed. It is claimed that ten-foot turbines would be most economical, where suitable, each of which would develop over 300 hp. with a five-foot head. Thus a mile of sea wall would be capable of generating approximately 120,000 hp.

Hog Fuel in the Pacific Northwest

Its Rise from the Dumps to a Revenue Bearing Commodity

Hog Fuel is the refuse from lumber made in the process of manufacture into boards and pieces of larger dimensions. It consists of broken slabs and pieces broken from timber, sawdust and other forms.

THE man who makes two blades of grass grow where but one grew before is always received with acclaim, and rightly. But somehow one's enthusiasm runs higher for the fellow who does things on a par with getting honest-to-goodness kilowatts from garbage. Such frugality is indeed uncommon in a new country. And so the story of exploiting the nuisance, hog fuel, in the Pacific Northwest is doubly interesting and valuable to those who now find it a burdensome waste.

When in Portland, Ore., recently, the writer, in scanning the newspaper over the coffee and rolls, noticed that a local lumber company was in the market for a burner to consume hog fuel, the accumulation of which was such a nuisance about the sawmill. It was going to cost many thousands of dollars for the consumer. And I had just come from Tacoma, Washington, not so many miles away, where R. L. Watts, mechanical superintendent for the St. Paul & Tacoma Lumber Co., was doing this refuse up in neat packages of freight-car and motor sizes and selling them to eager buyers in the picturesque city. And more—he furnished the purchaser, or could furnish him, with accurate information about heating value and moisture, and translate without hesitation the comparative cost with fuel oil on an evaporation basis.

Watts came to Tacoma from the desert country of New Mexico and Arizona. So he was greatly disturbed about the universal custom of conveying perfectly good fuel to burning dump piles and incinerators just to get it out of the way. Desert folks have to be frugal. The small mills usually convey the hog fuel to a point some little distance away, elevate it and let it fall upon a burning pile. Such practice succeeds in many locations in burning down the mills every few years, but no one seems to take this seriously. Fig. 3 shows a pile of hog fuel held in reserve at the plant of the St. Paul & Tacoma Lumber Co., Tacoma.

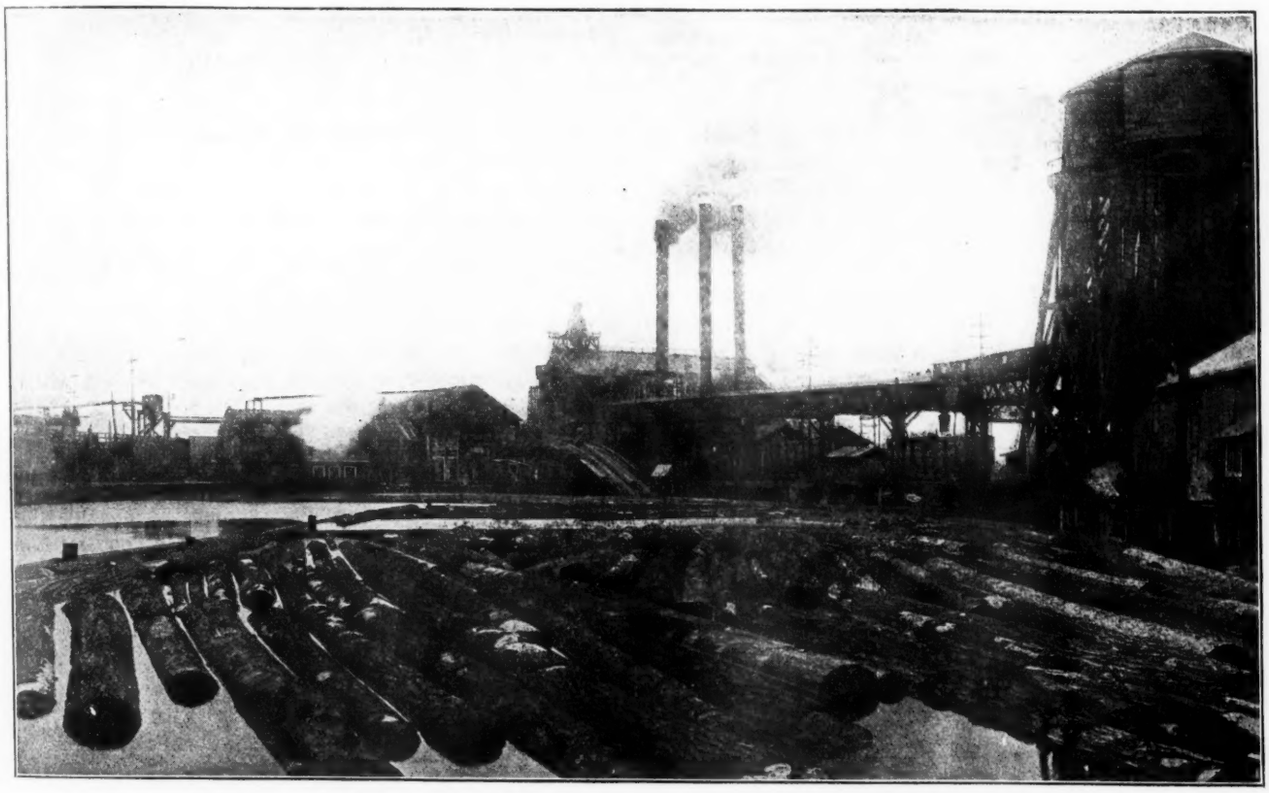


FIG. 1. PLANT OF THE ST. PAUL & TACOMA LUMBER CO.
To the right of the power plant and under the conveyor housing hog fuel is being loaded into cars for distribution in the city.

To understand the market for hog fuel one must realize the outstanding differences between Eastern and Western power situations. In the Pacific Northwest water power abounds, coal of inferior grade only is available, the climate is mild in winter, and the electric rates are, on the whole, low. So there are few independent power plants. District steam heating is common to the whole Pacific Coast. California fuel oil is widely used—in fact, is the chief fuel for power plants and steam boilers. A few years ago it cost much under a dollar, even in the Northwest. But now—well, it is impossible to guess what it will be there when this article appears, but it was uncomfortably crowding the

FIG. 2. TIMBER ARRIVING AT THE MILL FROM THE CAMP

All mechanical equipment at the camp and the mills is selected, operated and maintained under the supervision of the mechanical engineer.

two-dollar mark early in the year. In the face of these conditions, therefore, hog fuel, which averages 5,500 B.t.u. per lb. wet and 8,700 B.t.u. per lb. dry, offered possibilities to the St. Paul & Tacoma Lumber Co., whose great mills are near the center of the city. Fig. 2 shows a load of timber arriving at the mills.

Mr. Watts conducted tests the results of which are given in the accompanying table and which, it will be observed, show the fuel to be a good one. Curves of some test results are shown in Fig. 4. The district steam-heating station which supplies the business section of Tacoma with heat is one of the large consumers of hog fuel. Oil was used until recently, and the burners, tanks, etc., are still in place ready for use if necessary. The market value of the fuel is so great and the electric rates so low that the St. Paul & Tacoma Lumber Co. buys considerable current from the city and sells more and more hog fuel. The company will, of course, maintain its power plants, but will install another large steam turbo-generator and extend electrification of its many mills.

In and around Portland, Ore., hog fuel is becoming popular. Engineers there have learned to burn it with worth-while results.

The usual practice in using hog fuel is to convey it over the furnaces and drop it into open chutes which direct its fall into the tops of the dutch ovens.

At present hog fuel here is selling at $1.50 per unit (200 cu.ft.) loaded into the cars at the mills. The cars contain an average of 20 units. At the plant of the Tacoma District Heating Co., which purchases the largest volume of hog fuel, the cost of unloading the

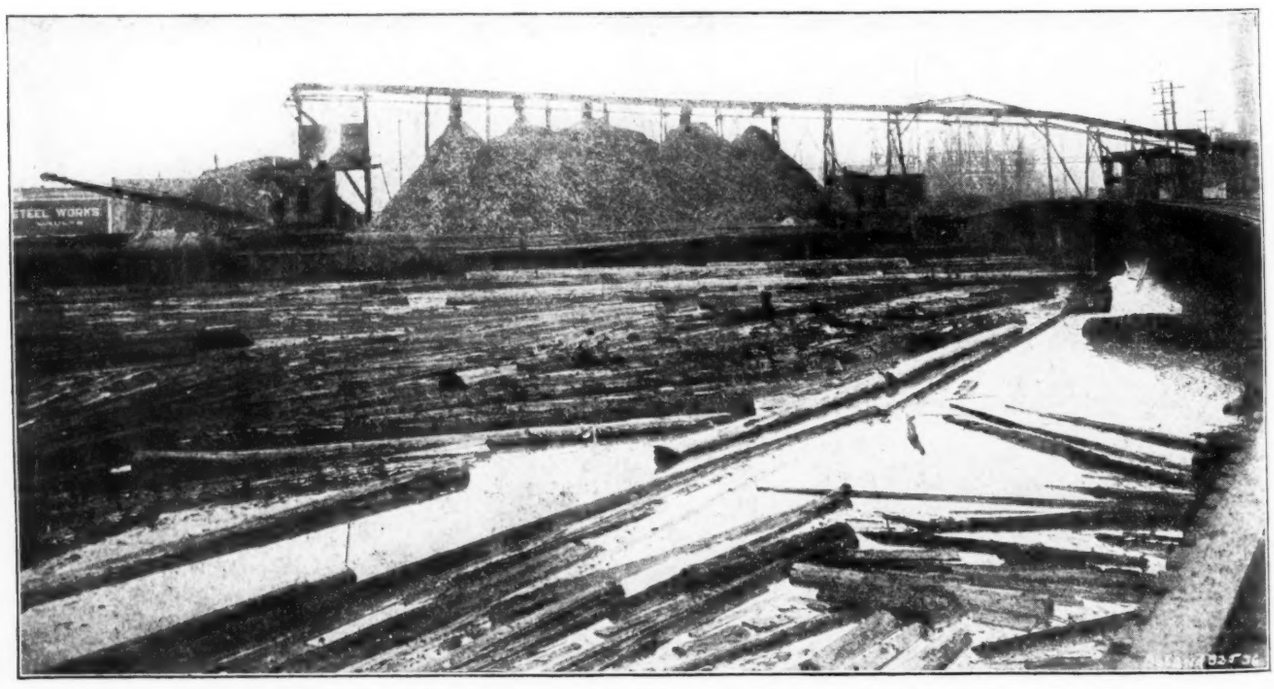


FIG. 3. PILE OF HOG FUEL IN RESERVE IN THE BACKGROUND

Note the long timber in the mill pond.

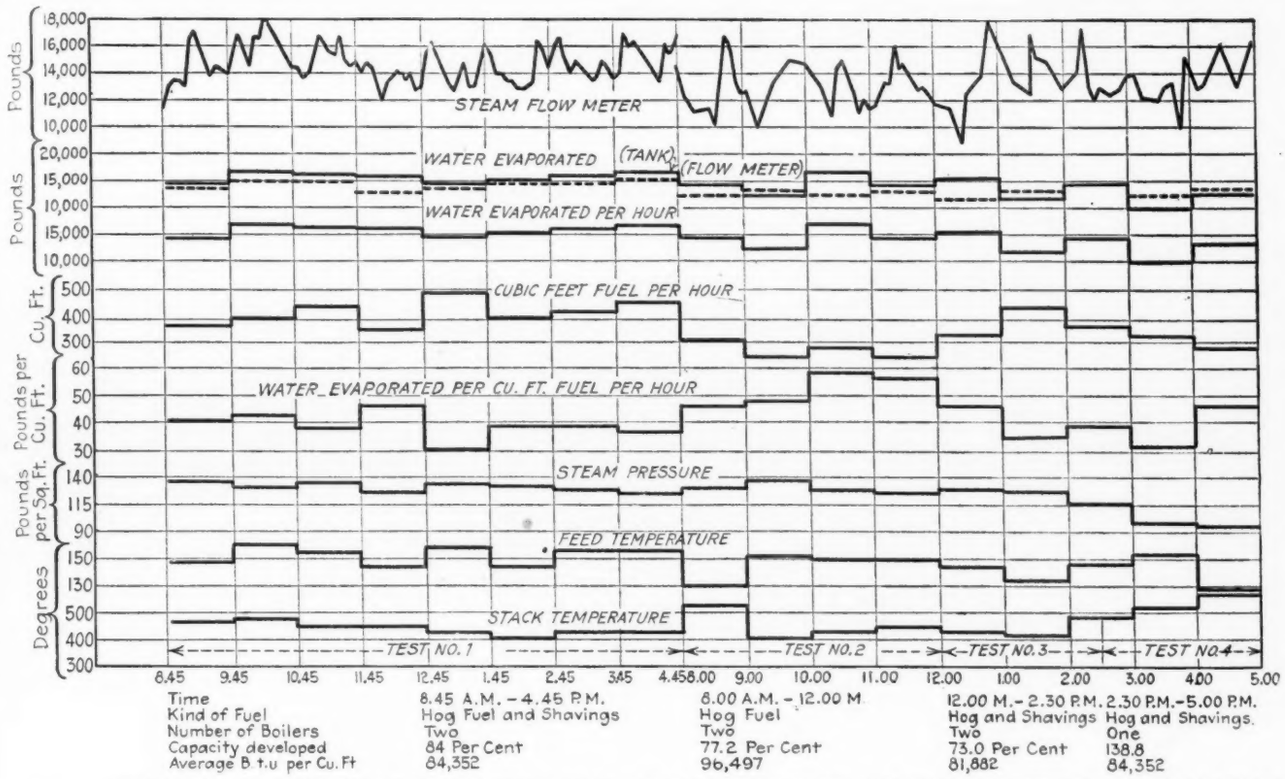


FIG. 4. PERFORMANCE RESULTS WITH HOG FUEL IN PLANT OF THE ST. PAUL & TACOMA LUMBER CO., TACOMA, WASH.

fuel from the cars to the boiler-house bunkers is 20c. per unit, or about $4 per car. Mr. Watts finds that the boiler-plant labor charge is practically the same as for plants burning coal with stokers and having overhead bunkers, with the exception that little or no charge is made for ash removal, with hog fuel. Numerous tests conducted by the St. Paul & Tacoma Lumber Co. show that an average of 10,000 lb. of water may be evaporated

TEST OF STERLING BOILERS USING WOOD FUEL

Location	St. Paul & Tacoma Lumber Co., Tacoma, Wash.				
Furnace, Dutch oven: length, ft				6.5	6.5
Grate surface, sq. ft				55.25	62.82
Water heating surface, sq. ft				2,617	2,878
Date, Feb. 20 and 21, 1917.					
				Average of	
Test number	1	2	3	1, 2 & 3	4
Duration, hr	8.0	4.0	2.5	14.5	2.5
Kind of fuel	Shavings and hog	Hog only	Shavings only	.....	Shavings and hog
Steam pressure, lb. gage	131	131	128	130	100
Temp. feedwater, deg. F.	153	145	143	147	142
Temp. escaping gases, deg. F.	413	427	430	423	531
Forced draft between damper and furnace, in water	0.2	0.2	0.2	0.2	0.2
Average weight of fuel per cu.ft. as fired, lb	15.32	18.37	14.64	16.11	1..75
Moisture, per cent	38.5	41.5	34.0	38.0	38.5
Heating value per lb. wet, B.t.u.	5,506	5,253	5,593	5,451	5,506
Heating value per lb. dry, B.t.u.	8,953	8,979	8,474	8,802	8,953
Cu.ft. fuel burned, per hr.	375	264	343	339	287
Cu.ft. per sq.ft. grate per hr.	3,176	2,236	2,905	2,871	2,431
Total evaporation from and at 212 deg. F., lb	127,469	58,737	34,602	221,108	31,311
Evaporation from and at 212 deg. F., per cu.ft. fuel as fired, lb	42.5	55.7	40.4	45.7	43.6
Evaporation per unit (200 cu.ft.) of fuel, lb	8,500	11,400	8,080	9,000	8,720
Boiler horsepower developed	462	425	401	430	363

(presumably from and at 212 deg. F.) per unit of hogged fir. The average evaporation from a barrel of oil as delivered in Tacoma is 4,368 lb., and from a ton of local coal about 12,000 lb.

Following are some figures of comparative costs with oil, coal and hog fuel as related to the Tacoma Shops power plant of the Chicago, Milwaukee & St. Paul R.R.; the report was made in October, 1918, when all fuel prices were lower than at present:

OIL:	
Average daily steam load, lb	416,000
Barrels oil used per 24 hours	95
Pounds steam per barrel (evap. 13-1) (bbl. 336 lb.)	4,368
Cost of oil per barrel	$0.75
Cost of oil per day	71.43
Cost of steam per thousand pounds	0.1717
COAL:	
Average daily steam load, lb	416,000
Tons coal used per 24 hours	34¾
Pounds steam per ton (evap. 6-1; ton, 2,000 lb.)	12,000
Cost of coal per ton	$2.75
Cost of coal per day	95.56
Cost of steam per thousand pounds	0.229
HOG FUEL:	
Average daily steam load, lb	416,000
Units hog fuel used per 24 hours	41.6
Pounds steam per unit (unit 200 cu.ft.; evap. 50-1)	10,000
Cost of hog fuel per unit	$0.75
Cost of hog fuel per day	31.20
Cost of steam per thousand pounds	0.075

The foregoing figures cover cost of fuel only and are based on standard plant practice.

Some weeks ago a trial of hog fuel was made on an 8-retort underfeed stoker in one of the stations of the Portland Railway, Light and Power Co., Portland, Ore. The fuel was placed by hand through three large doors cut in the front of the boiler setting, directly over the stoker retorts. The chief difficulty was that the fuel could not be handled by the stoker fast enough to keep the rear grates covered. The fuel was placed on the forward grates in a thick bed which gradually thinned out as the rear grates were reached; rapid combustion therefore took place at this latter end of the stoker. The engineers in charge of the plant are of the opinion that if the thick bed of fuel could be maintained at the rear of the stoker instead of at the front, this method would be highly satisfactory.

The method of firing affected the rate of steam flow: the flow-meter chart showed plainly when each boxful of fuel was charged and when the doors were closed after charging. While charging, the percentage of rating

would drop to about 120 per cent normal, and rise to 225 per cent normal when closed, reaching 260 per cent for about five minues after charging and closing the doors. The charging periods occurred about every fifteen minutes.

The combustion over the active part of the grate surface was good, the flame being a brilliant white, short and quick. There was no secondary combustion in the boiler passes. However, combustion occurred too close to the tubes.

The following is a brief tabulation of the principal results obtained during the test:

Duration of test—6 hours (9:30 a.m. to 3:30 p.m.)	
Average steam pressure, lb.	187
Average steam temperature, deg. F.	572
Superheat, deg. F.	96
Factor of evaporation	1.248
Pounds of water per pound of fuel	2.58
Pounds of water per pound of fuel, from and at 212 deg. F.	3.21
Rating obtained (average per cent, normal)	175
Average weight of fuel per cu.ft., lb.	15.8
Water evaporated from and at 212 deg. F. per unit of fuel, lb.	10.142
Flue gas analysis (average):	Per Cent
CO_2	11.16
O	8.57
CO	0.28

Surcharging Diesel Engines

A Practice of Especial Value When Operating at High Altitudes

By CL. RUEGG

SINCE the introduction of the two-cycle Diesel engine, necessitating the use of a scavenging cylinder it has been an open question as to what capacity this pump should have in order to supply sufficient air to each engine cylinder for complete combustion. Discussion as to the proper size of such scavenging cylinders, or pumps, has led to considerable experimentation and has resulted in more or less standardized sizes that are not only sufficient for thorough scavenging, but also make available a surplus of air. While this surplus of air cannot be taken advantage of under ordinary conditions to burn a greater amount of fuel, it is particularly useful at high elevations.

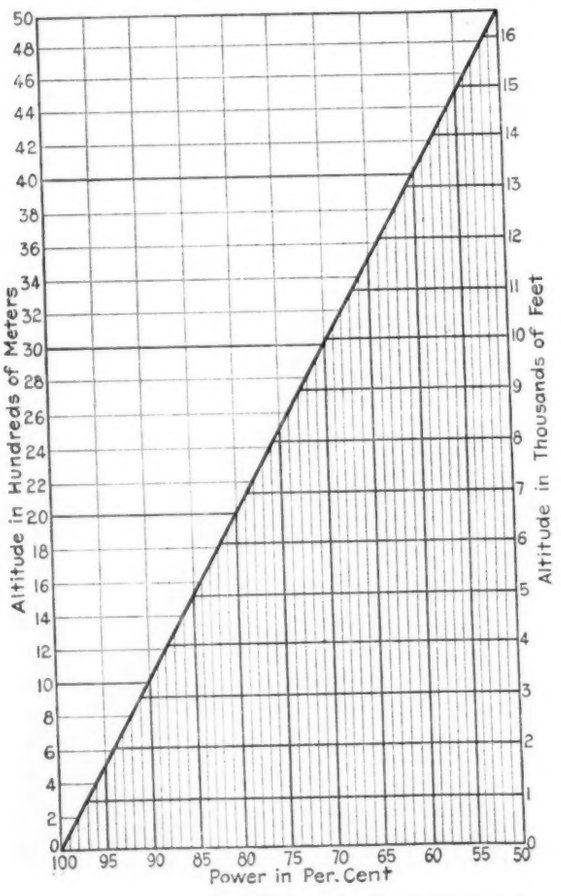


FIG. 1. CHART SHOWING DECREASE IN POWER WITH INCREASE IN ALTITUDE

The quantity of fuel that can be burned in a Diesel-engine cylinder is limited by the amount of heat that can be carried off by the jackets. Any increase in the amount of fuel above this maximum will result in more power, but also in an accumulation of heat, which will cause injurious cylinder temperatures.

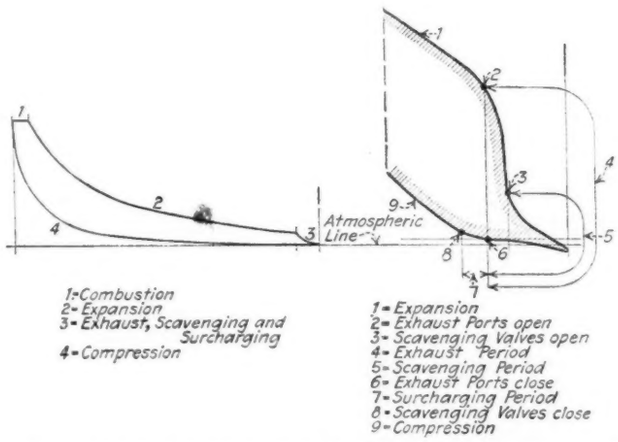


FIG. 2. TYPICAL TWO-CYCLE DIESEL-ENGINE INDICATOR CARD. FIG. 3. ENLARGED TOE OF THE INDICATOR CARD SHOWN IN FIG. 2

The quantity of fuel that can be *economically* burned in a Diesel-engine cylinder is limited by the weight of air in the cylinder. If this weight of air is decreased, the amount of fuel injected must be decreased, with a resulting loss of power. Any attempt to force up the power output by injecting more fuel results in inefficient operation with its accompanying increase in the amount of heat to be carried off by the cooling system.

It is well known that both the density and temperature of the atmosphere decrease with the altitude. It may, however, be assumed that the initial working temperature of the cycle is not affected by the altitude and that in actual practice the charge entering the cylinders is maintained at a constant temperature. Decrease in power with increase in altitude is shown in Fig. 1. The volumetric efficiency of an engine cylinder remains almost constant at various altitudes, and the volume drawn into the cylinder either at sea level or at any other altitude is approximately the same. The weight of the air taken in, therefore, varies in direct proportion to the atmospheric density. It will be noticed that there is a considerable decrease in pressure and therefore in density of the atmosphere with the altitude, and

a similar decrease in the output of the engine must be anticipated if no means are provided for surcharging the cylinder with air. In other words, the power developed per cylinder is directly dependent on the weight of the charge of air in the engine and not on its volume, and this weight decreases at higher altitudes.

In a four-cycle Diesel engine the pistons have two functions to perform—that of a power piston and that of a scavenging piston. The amount of air taken in during the suction stroke is less than 100 per cent of the piston displacement, owing to the fact that a loss through the inlet valve is occasioned by very high air velocities. In some instances this loss amounts to from 5 to 10 per cent. There is no way to increase the amount of air delivered to a cylinder of a four-cycle engine, except by the use of a separate blower or surcharging pump. Supercharging has made it possible to obtain mean pressures as high as 260 lb. per sq.in. in special engines. The operation of a two-cycle Diesel engine is so well known that its details need not be discussed here. A typical indicator card from such an engine is shown in Fig. 2. Line 4 indicates the compression; line 1, burning at constant pressure; line 2, expansion of the burned gases to a point where the piston uncovers the exhaust ports; and line 3, the drop of pressure within the cylinder as the burned gases escape through the exhaust parts. It is this last part of the cycle in which we are particularly interested. Referring to Fig. 3, point 2 indicates the instant when the piston uncovers the exhaust ports. The large area thus opened causes the rapid drop of the pressure. Point 3 on the exhaust line indicates when the scavenging valves open. The air immediately rushes into the cylinder, because a lower pressure exists within the cylinder than behind the scavenging valves. It is usually found that the momentum of the exhaust gases carries the pressure slightly below atmospheric, as shown in Fig. 3, during which time, however, the scavenging air is continually blowing into the cylinder. At the instant the piston covers the exhaust ports, as indicated by point 6, all air that is entrapped between the piston and the head suffers an increase in pressure, inasmuch as the scavenging valves are still open and continue to admit air into the cylinder. When the point 8 is reached, the scavenging valves close and compression begins. It is therefore evident that a greater weight of air is now within the cylinder than would be present without supercharging. The same cycle is illustrated in Figs. 4, 5, 6 and 7, the arrows indicating a rush of burned gases out through the exhaust ports. Fig. 5 also illustrates the impor-

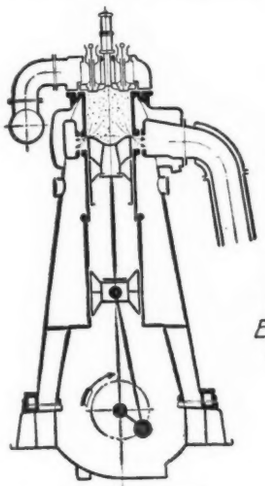


FIG. 4. TWO-CYCLE DIESEL ENGINE DURING EXHAUST

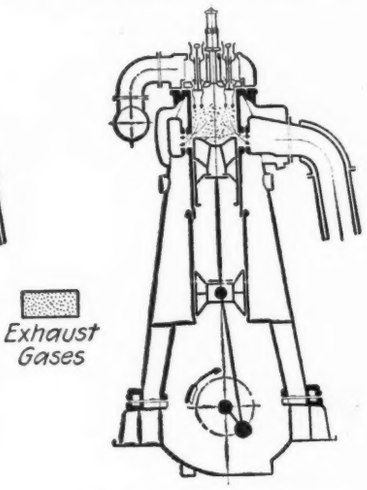


FIG. 5. TWO-CYCLE DIESEL ENGINE DURING SCAVENGING

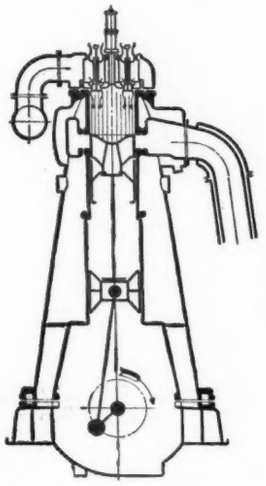


FIG. 6. TWO-CYCLE DIESEL ENGINE DURING SURCHARGING

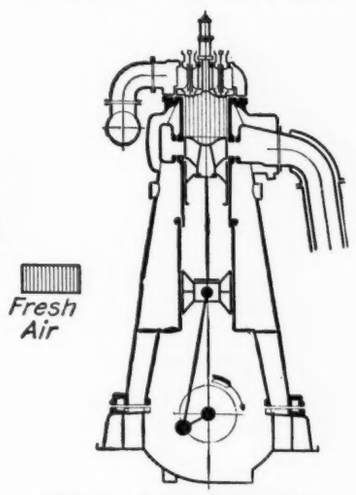


FIG. 7. TWO-CYCLE DIESEL ENGINE DURING COMPRESSION

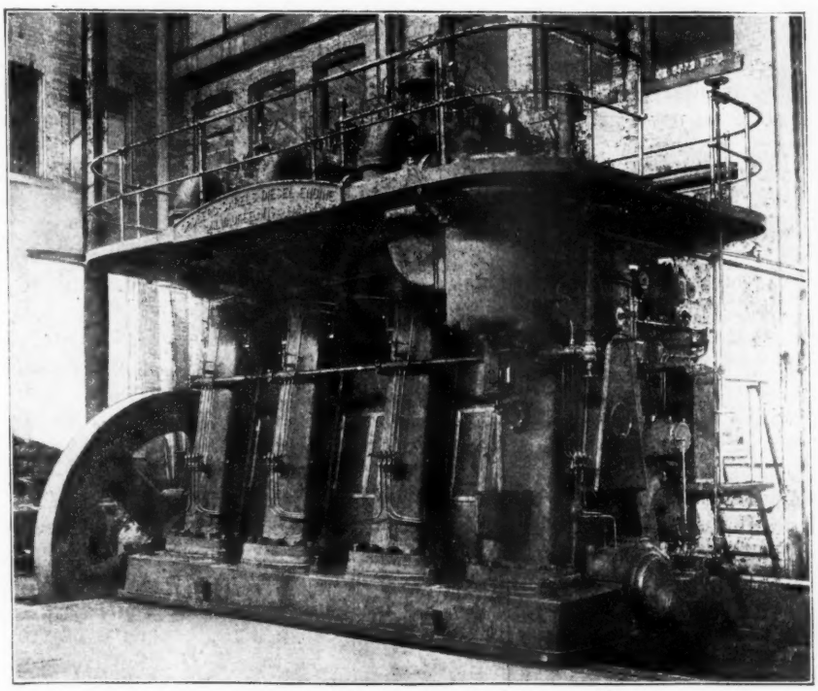


FIG. 8. TWO-CYCLE DIESEL ENGINE FOR DIRECT CONNECTION TO AIR COMPRESSOR

Supercharging has been successful with this engine, although its speed varies from 180 to 70 r.p.m.

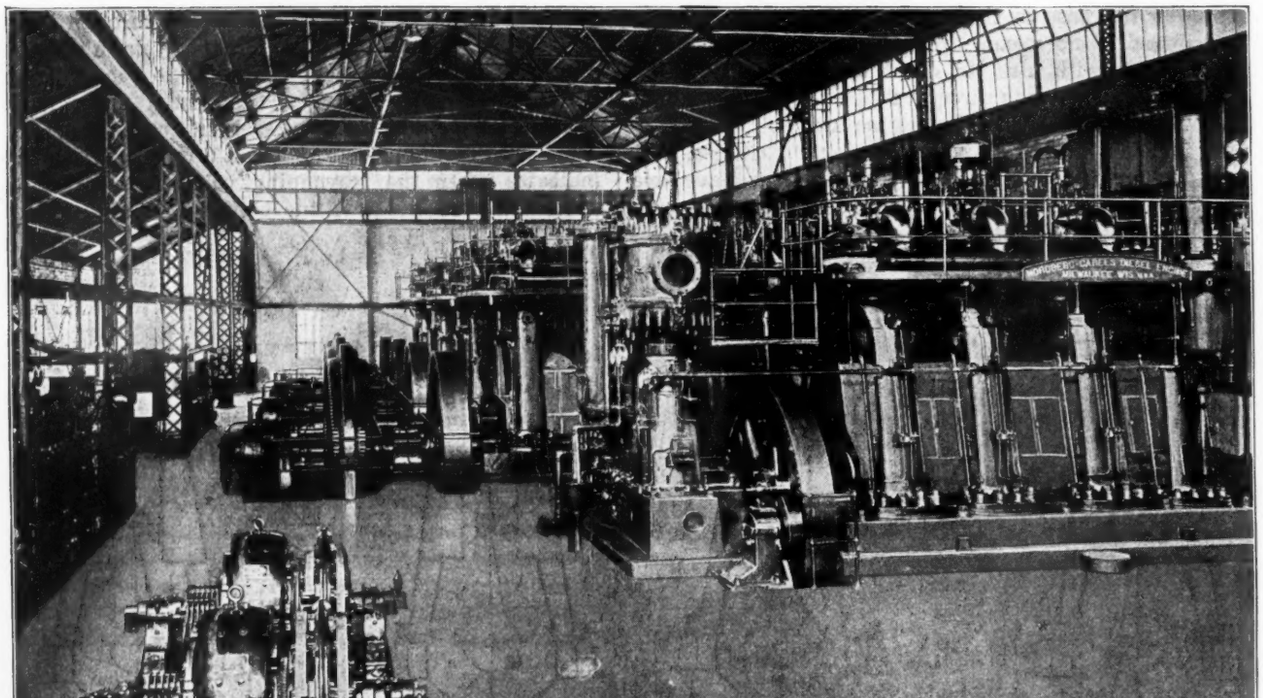


FIG. 9. DIESEL ENGINE DIRECT-CONNECTED TO AIR COMPRESSOR AND FOUR SUCH ENGINES DIRECT-CONNECTED TO GENERATORS

This plant operates at 6,000 ft. above sea level, and its present capacity is maintained by surcharging.

tance of placing the scavenging valves in the head, thereby allowing the fresh air to push ahead of it the exhaust gases.

Fig. 6 shows the piston at the moment the exhaust ports are closed. The cylinder is now filled with fresh air, but the scavenging valves are still open and the cylinder is being surcharged. As indicated in Fig. 7, the scavenging valves are closed and compression begins.

The scavenging pumps are designed to deliver air at a gage pressure of 3 to 5 lb. per sq.in., depending on the size and type of the scavenging valves. There is no atmospheric inlet valve, and the scavenging air is admitted into the cylinder either through valves in the cylinder head or through ports near the bottom of the cylinder. In either case the piston, when closing the exhaust ports during the compression stroke, starts to compress the pure air at a pressure above atmospheric.

Scavenging ports are usually located opposite the exhaust ports, while valves are generally in the cylinder head. The latter arrangement has several advantages: First, an even distribution of scavenging air entering the cylinder is assured, and, further, the opening of the valve can be timed to suit the conditions. Probably the most important advantage, however, is that the cylinder dimensions are not limited to any fixed ratio between stroke and bore, as is the case with port scavenging.

It is quite important to be able to vary the amount of air as well as the amount of fuel taken into the cylinder, and with two-cycle engines this is accomplished by properly dimensioning the scavenging pump. Usually, this pump furnishes 10 to 40 per cent more air than is represented by the piston displacement of the power cylinders.

It has been claimed that the benefits derived from surcharging would not be realized in cases where the speed of the engine was not constant. The engine which is shown on the testing floor in Fig. 8 has been direct-connected to an air compressor operating between 180 and 70 r.p.m., in which the scavenging pressure varies with the speed, dropping from about 4 lb. at 180 r.p.m. to about 1¾ lb. at 70 r.p.m. The fuel consumption per indicated horsepower during this range of speed remains constant. This is due to the fact that being direct-connected to a compressor, the torque on the machine remains the same at all speeds, and it was found that the fuel consumption per stroke was practically independent of the speed.

Fig. 9 shows in the foreground, a compressor of 4,000 cu.ft. of free air per minute capacity installed in a Diesel plant, together with four Diesel units direct-connected to alternating-current generators running in parallel. The plant is in operation at an elevation of about 6,000 ft., and the effect of surcharging made it possible to rate these engines higher than is indicated by the curve of Fig. 1.

The total amount of capital invested in central stations in the Dominion of Canada, inclusive of transmission and distribution systems, is $369,464,961, an average of $210 per installed primary horsepower. The total construction cost of seventy representative hydro-electric stations, exclusive of transmission and distribution systems with an aggregate turbine installation of 745,797 hp. is $50,740,468 (pre-war figures). The cost of the construction of dams, flumes, penstocks and all hydraulic works is included in the figures given, as well as power stations and equipment.

Storage Batteries for Emergency Service

Emergency Batteries Classed as Stand-by, Exciter and Oil-Switch Batteries, 159 Stand-by Batteries in Service Having a One-Hour Discharge Rate of 633,000 Amperes. End-Cell Switches Built to Handle 50,000 Amperes. Control of Exciter and Oil-Switch Batteries. Storage Batteries Recommended for Emergency Lighting.

By C. J. WELCKE
Engineer, Electric Storage Battery Company

WITH the ever-increasing development in the generation of electric power by both steam and hydraulic stations, it is becoming more and more important that continuity of service be maintained and that power interruptions be reduced to a minimum. In eliminating interruptions of service the lead-acid type of storage battery has been and still is an important factor.

C. J. WELCKE

The storage battery is particularly suited for emergency service on account of its extreme reliability. It is simple in construction, there are no moving parts to get out of order, and it is capable of instantly giving out energy at extremely high rates, with a very small drop in voltage. In fact, in actual practice the rate at which energy can be taken from a lead-acid storage battery is limited only by the size of current-carrying parts. Combined with its abilty to deliver tremendous amounts of power for short periods is the further advantage that it is an efficient piece of apparatus and requires comparatively little care or attention. One of the most important characteristics of the storage battery, which renders it adapted to emergency stand-by service, is its constant readiness to respond to demands for power without the continuous losses and cost of attendance required by moving machinery.

Storage batteries for emergency service in connection with electric-power supply are principally used in three ways: large stand-by batteries in use on direct-current systems of distribution in the larger cities; exciter batteries used in alternating current generating stations—both steam and hydraulic; and oil-switch batteries in generating stations and substations. It is the general practice to make use of emergency batteries that have been installed in power plants to furnish emergency lighting for the plant itself. Where such a battery is not available, a small battery can be installed especially for this service at moderate cost.

Stand-by batteries are generally of large size and are connected at all times to the direct-current distribution system. In this way they act as reservoirs of energy, always ready for instant use in cases of emergency or breakdown. An interesting emergency condition often develops in cities in the case of a sudden thunderstorm,

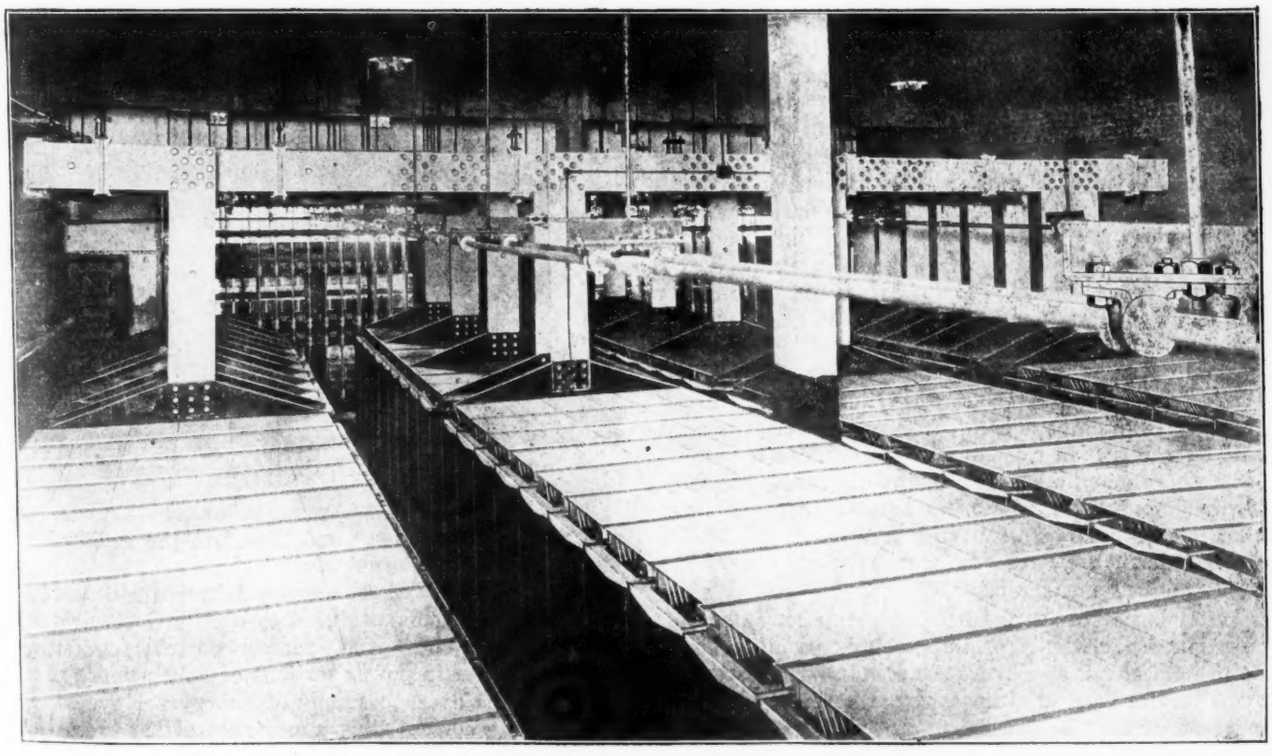


FIG. 1. LARGE STAND-BY BATTERY; CONNECTION TO END-CELL SWITCH IS SHOWN IN THE BACKGROUND

when the power demand may increase so rapidly that additional generating apparatus cannot be brought into service quickly enough to meet the requirements. As batteries of this type are called on for comparatively infrequent discharges, a type of plate construction is used which will give a maximum capacity at high discharge rates with a minimum weight and floor space.

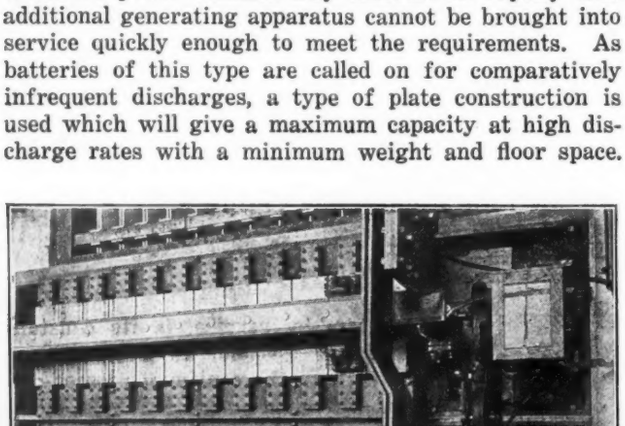


FIG. 2. FRONT VIEW OF END-CELL SWITCH

In Fig. 1 is shown a stand-by battery, the plates of which are installed in large lead-lined wooden tanks.

In order to vary the voltage of these batteries so that they may float on busses of different voltages and also that the total number of cells may be quickly put in circuit in an emergency, a certain number of the cells, known as "end cells," are connected to a suitable switch so that they can be cut in and out of circuit as desired. These end-cell switches, one of which is shown in Fig. 2, are worked automatically by a push-button on the power-house or substation control board. Since the circuit must not be opened when cutting the end cells in or out, it is necessary to momentarily partially short-circuit them as the brush travels over the contacts, and this short-circuit current, in the case of the large cells, would exceed 150,000 amperes if means were not provided to limit it to a safe value. Therefore the design and construction of these large switches is an engineering problem of no small magnitude.

End-cell switches must have sufficient capacity to carry any current the battery can furnish, even under short-circuit conditions. The largest size is designed to handle a discharge of 40,000 to 50,000 amperes for a few minutes, to which must be added the heavy local currents across the contacts, when the traveling brush is moving from point to point. There are today installed or under contract in this country and Canada a total of 159 of these stand-by batteries, the aggregate capacity of which approximates 633,000 amperes for one hour at 250 volts, the largest having a capacity of 12,600 amperes at 250 volts for one hour. Several others are of only slightly smaller capacity.

Exciter batteries are used for insuring continuity of field-excitation current for alternating-current generators in both steam and hydraulic plants. The batteries in this service may be of large size, where the demands are great, or may be of smaller size in glass jars, Fig. 3, where the excitation currents are not so large. As in the case of stand-by batteries, exciter batteries are sometimes floated continually on the bus, or they can be arranged as shown in the diagram, Fig. 4. With this arrangement the battery is divided into two groups and these two groups are connected in parallel and receive a small charge, known as a "trickle charge," from the exciter bus through the trickle-charge resistance or lamps. The purpose of this trickle-charge is to keep the battery always in a fully charged condition and compensate for any local internal losses in the battery.

For the regular charging of the battery a pair of fixed resistances are provided and the two groups charged in parallel from the exciter bus through these resistances. This regular charging of the batteries is necessary only at intervals of one to two weeks and only for a period of about one hour at such times.

If for any reason the voltage of the exciter bus fails or drops below a predetermined value, the contact-making voltmeter operates and causes the automatic switch to close. This action places the two groups of the battery in series across the exciter bus, and the battery automatically picks up the exciter load without any interruption to the service. As a signal that the switch has been closed and the battery thrown on emergency discharge, an electric horn, alarm bell or signal lamp can be made to operate by the automatic switch, thus attracting the attention of the attendants.

With the arrangement shown the battery is discharged only in an emergency and normally does no work at all, so that a battery connected and operated in this way will have a very long life. It can readily be seen that this arrangement has certain advantages over floating the battery directly on the exciter bus, particularly where the alternator's voltage is controlled

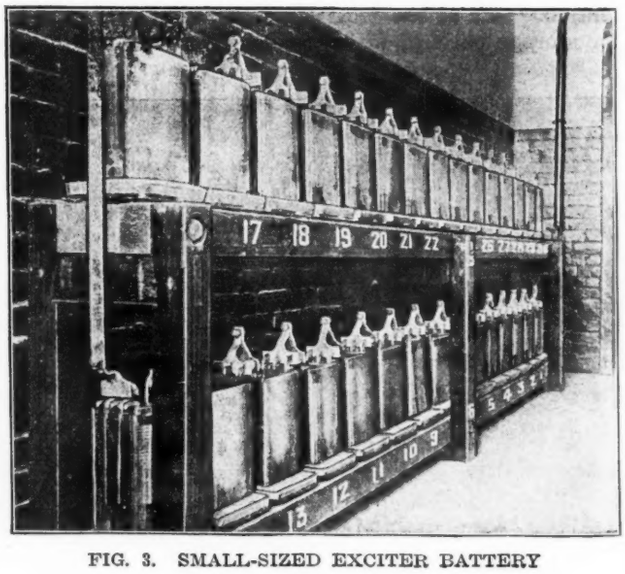


FIG. 3. SMALL-SIZED EXCITER BATTERY

by a "Tirrell Regulator," and therefore the exciter-bus voltage varies considerably.

In oil-switch service the storage battery furnishes the momentary high currents used to open and close automatic oil switches and remote-control regulating apparatus either in power stations or substations. For furnishing the average supply of energy for operating these various devices it is standard practice to install a motor-generator set consisting of an induction motor,

driven by power from the alternating-current circuit, directly connected to a direct-current generator. The storage battery normally floats across the terminals of the direct-current generator, which is kept running continuously, except for such periods when it may be necessary to shut down for inspection or repairs. The generator carries the steady load of the signal lamps plus a small charge to the battery to provide for the average demand of the oil switches. For this purpose the direct-current generator should be shunt wound, so that when the heavy demand occurs, due to the opening or closing of the switches, its drooping voltage characteristic will allow the battery to take nearly all the excess load.

It is evident that if a battery were not provided, the motor generator would have to be of sufficient capacity for the maximum demand and would therefore be many times larger than when a battery is used. Also, with a motor generator only, there is no reserve feature whatever. If a direct-current circuit of sufficient voltage is available, such as on a trolley or third-rail system, the battery may be floated and charged from this circuit through suitable resistance, and in this case no separate motor generator would be required.

The normal voltage of oil-switch control circuits is approximately 125 volts and generally sixty cells of battery are used. A diagram of the standard method of connecting an oil-switch battery, using a motor-generator set, is shown in Fig. 5.

In order to permit charging the battery to maximum voltage by raising the potential of the generator without subjecting the signal lamps and remote-control apparatus to this high voltage, a tap is taken from the battery to the switchboard by means of which a group of ten cells may be cut out. At the beginning of charge the entire sixty cells are connected to the generator whose voltage is raised sufficiently to deliver the charging current, while fifty cells are connected across the control circuit. The current required for the signal lamps under these conditions passes through the end-cell group in addition to the charging current of the main battery and the charging of the end cells is, therefore, completed before that of the main battery. The end-cell group is then cut out, and the charging of the remaining fifty cells is completed. The maximum voltage of these fifty cells at the end of charge may be nearly 140 volts. The signal lamps will stand this voltage for a short time, and the standard remote-control apparatus will operate satisfactorily at this voltage.

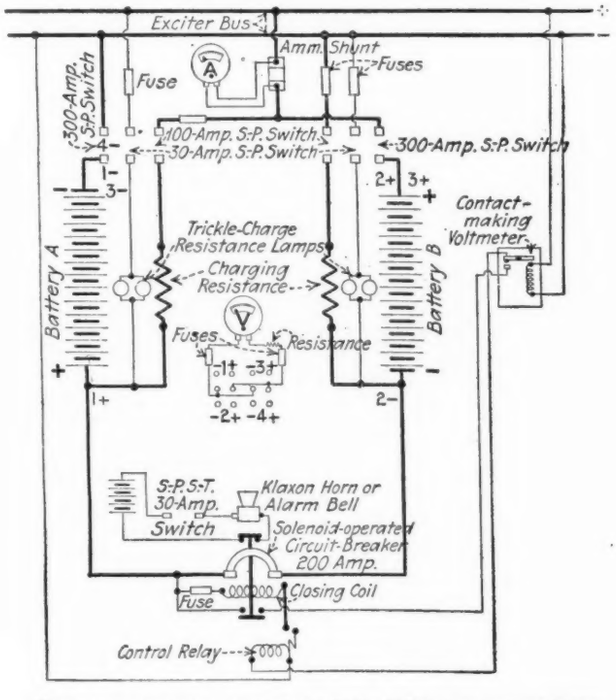


FIG. 4. WIRING DIAGRAM FOR EXCITER BATTERY

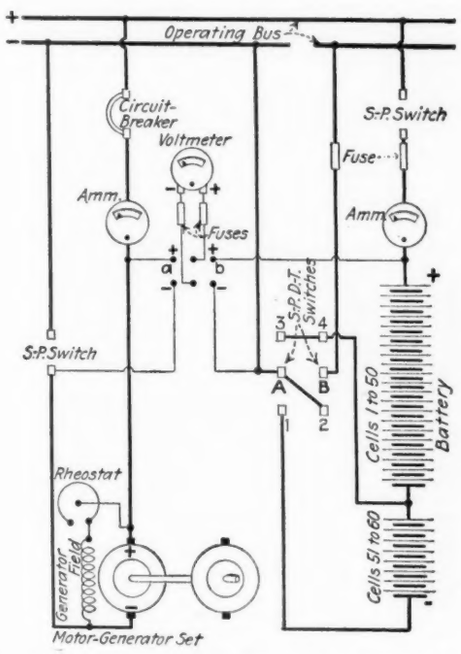


FIG. 5. WIRING DIAGRAM FOR OIL-SWITCH BATTERY

In the diagram, Fig. 5, the negative bus is divided into two sections, and two single-pole, double-throw knife switches *A* and *B* are provided, one connected to each section of the negative bus. When *A* is thrown down, the 60 cells of battery are connected across the generator terminals, and when *B* is thrown down, the two sections of bus are connected together and current is furnished to the control circuit by the generator with the battery floating in parallel with it. This is the normal position of these switches.

At the beginning of charge switch *B* is thrown up, connecting the control circuit across fifty cells and the voltage of the generator, which is still connected across sixty cells, is raised until the desired charging current is obtained. When the end group is fully charged, as indicated by free gassing and a maximum specific gravity, switch *A* is thrown up, cutting out the end-cell group and the charging of the main battery is completed.

Oil-switch batteries have sometimes been operated on what is known as the "straight charge and discharge method." That is, the battery, instead of being continually floated on the motor generator or charging source, is alternately charged and then allowed to carry the entire oil-switch and remote-control load. This involves working the battery to a considerable extent, and, therefore, the life of the plates will not be so long as where the battery is floated on the charging source, as previously described. Also, to furnish a reserve, a

FIG. 6. FOUR-CELL TRAY UNIT OF AN OIL-SWITCH BATTERY SEALED RUBBER JARS

larger battery is required, and even with a larger battery there is always the liability of an emergency occurring with the battery in a discharged condition, which is not the case where the battery is floated; therefore the straight charge-and-discharge method is not recommended except in cases where it is impossible for some reason to float the battery.

Oil-switch batteries usually are of the glass-jar type mounted on wood racks and installed in separate rooms provided for them. Where a separate room is not available, a type of battery has recently been developed especially for oil-switch service, consisting of heavy elements in sealed rubber jars, assembled in wood trays. A four-cell tray unit of this type of battery is shown in Fig. 6. This type of battery is shipped filled with electrolyte and charged, and is ready for service as soon as received. On account of its sealed construction it can be placed in any convenient place.

In all the foregoing classes of service the installation of the storage battery provides another valuable feature mentioned in the early part of this article, and this is current for a number of lights in the power station or substation in an emergency. Those connected with power-plant or substation work realize the importance of sufficient suitable light in an emergency or shutdown in order to make repairs or get the station in operation again, and there is no piece of apparatus so suitable for this purpose as a storage battery. For operating a few lights only, a very small battery is required, and as it would be used very little, the depreciation and maintenance items would be small.

Precautions When Pumping Ammonia from Coils

By B. E. HILL
Formerly Refrigerating Engineer, Armour & Company, Chicago

TO CLEAN the evaporating coils it will be necessary to transfer the ammonia from the evaporating coils to the condenser, and in case the coils are submerged in a brine tank the engineer should make certain that there are no leaks before pumping them out.

The brine can be removed before pumping out, but in this case air would be taken into the system. The proper thing to do is to assure oneself that there are no leaks and then proceed to pump the ammonia out of the coils before the brine is removed, as by so doing the brine will evaporate the liquid ammonia much faster. After the coils have been pumped down to as low a vacuum as possible, shut the main liquid and suction valves, and then the tank coils can be opened without any loss of ammonia due to unevaporated ammonia lying in the coils.

A sure method of cleaning these coils, after first removing the headers, is to take each one separately and connect up a steam hose of sufficient size to get a high velocity of steam traveling through the length of the coil. The heat from the steam will warm the oil, and the velocity of the steam will carry it through and discharge oil and dirt. When the oil is all out, disconnect the steam hose and attach an air hose, which will absorb and carry out the moisture remaining in the pipe, as the walls of the pipe will remain heated a sufficient length of time to evaporate the moisture and allow it to be carried out, which will leave the inside surface clean and dry. After all rubber joints have been examined, tightened and replaced where necessary, the coils are ready to be connected and put in service. In pumping out direct expansion coils, especially where the coils are in coolers where the ammonia fumes are absorbed by the stored products, extreme care should be taken to see that there are no ammonia leaks when the coils are opened.

There is considerable damage frequently produced in pumping out direct expansion coils. The only safe and sure method of pumping out these coils is to find all the low spots in the coils and wherever "live" frost is found, apply the *stick test*, as before explained. Do not open the coil; just hold a vacuum and drive out the liquid ammonia by applying heat—blowtorch, steam or hot water—till there is no *stick*, and where there is no *stick* there is no liquid, and it will be safe to open the coil.

It is well to take the extra precaution to open a line leading to the coil somewhere outside the cooler, as there may be a leaky valve, and in this case it may be necessary to put in a "blind" outside the cooler.

To simply pump a high vacuum on the coils is no assurance that the coils are empty in the case of a direct-expansion system. Take an ammonia test tube and fill it with liquid anhydrous ammonia to the amount of 50 or 100 c.c. and allow it to evaporate in a room where the temperature ranges from 90 to 100 deg. F. Note how long it will take to evaporate. This will give the engineer an idea of how long he will have to hold the vacuum on a direct-expansion coil in a cold room for the ammonia to evaporate. The vacuum gage may show a good vacuum for an hour or two without perceptible loss after being pumped down and still leak when the coil is opened and warm air comes in direct contact with the remaining liquid inside the pipes. The better way is to make sure by hunting up the traps or low places in the pipe lines and then apply the *stick*

test, which will show if there is any liquid remaining in the lines.

The writer has taken a test tube and filled it up to the 50 c.c. mark, placed the cork in the test tube and connected a hose to the glass tube that is inserted in the cork, and pumped a vacuum of 24 in. At first the liquid ammonia boiled violently, as the reduction of the pressure from atmosphere to 24 in. or 12 lb. below atmosphere greatly reduced the boiling point, but as the frost formed around the outside surface of the testing bottle, the boiling settled down shortly until it was barely perceptible and required an hour or so to complete the evaporation.

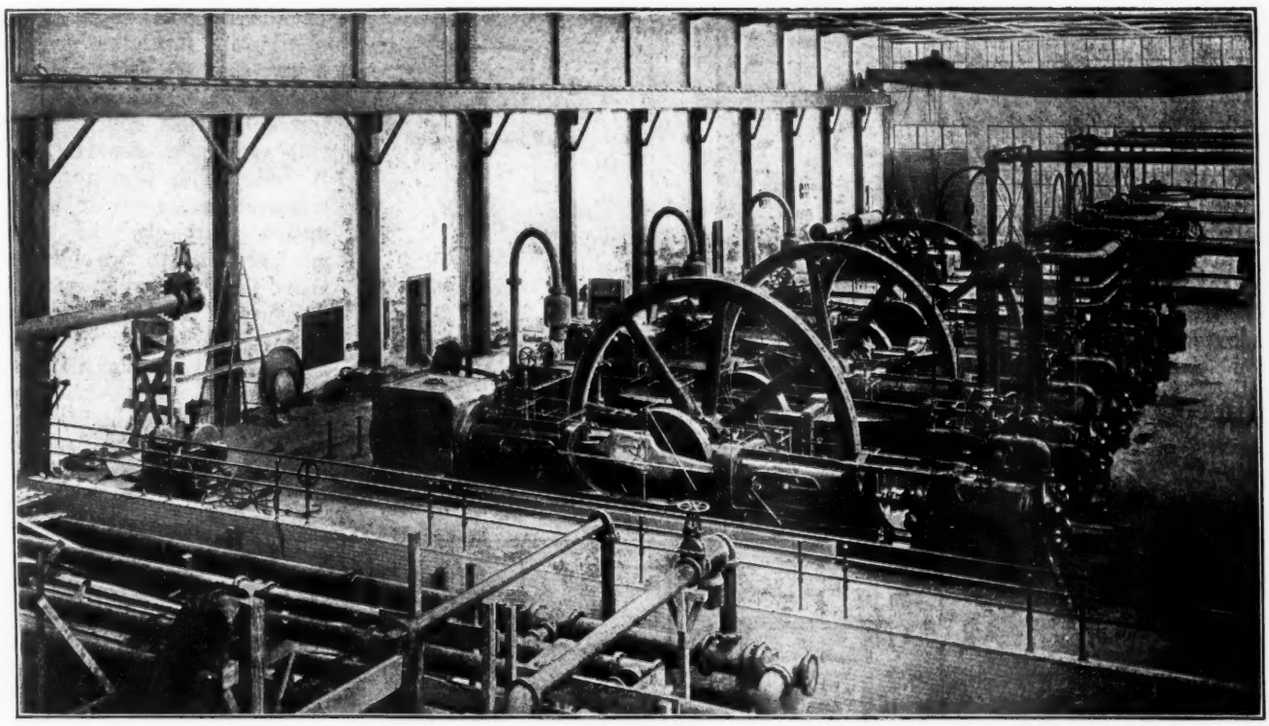
If desirable to make a test for the purity of ammonia, secure a test tube or flask, which usually bolds from 50 to 100 c.c. The flask, if made to test with 100 c.c., is made with the bottom end reduced in size to 1 c.c. and the 1 c.c. is graduated in ten parts, the lines being etched on the glass, each line representing one-tenth of one cubic centimeter.

To take a sample from a cylinder of anhydrous ammonia, use a copper wire and make one turn around the test tube, twisting the two ends of the wire together to form a handle. Next connect a short pipe to the valve on the cylinder and open slightly, holding the testing flask so that the liquid will fill the flask up to the line marked 100 c.c.; next place the cork in the flask, which is provided with a glass tube, bend to a half circle to allow the gas generated by the boiling liquid to pass out without raising a pressure, and the cork is placed in the tube to prevent the moisture in the air from coming in contact with the liquid surface of the ammonia, which would take up the moisture and give an incorrect reading. The flask is then immersed in salt or calcium brine at a temperature of 60 or 70 deg. F. and allowed to remain there until the liquid is all evaporated. If the liquid is pure anhydrous ammonia, the evaporation will be complete, but if there is an oily residue or clear substance remaining in the bottom of the tube, the ammonia is impure, and the percentage of impurities by volume is determined by the amount of residue remaining in the one graduated c.c. part of the testing flask.

Suppose the remaining impurities in the one graduated c.c. should be full up to the tenth line, or one c.c. remaining. There being 100 c.c. in the flask to start with, the impurities would be 1 to 100 or 1 per cent by volume, which is a greater impurity than is ever found. The percentage of impurities, however, is read direct from the test tube, and from the foregoing it is easy to read the percentage at any other point; say, two lines high would represent two-tenths of one per cent, or two c.c. to one thousand, etc.

Besides the liquid and solid impurities there are others commonly referred to by engineers as "foreign gases," the most common to be found in the ammonia cylinder being air or modified air, pyridine, chlorine, etc.

To determine the amounts of these gases would require the services of a chemist, and as the leading manufacturers of today have reduced these gaseous impurities to a minimum, it would not be of enough concern for the engineer to go to this expense. He can, however, raise the valve end of an anhydrous ammonia cylinder to be tested about six or eight inches high, turn the valve so that its opening will look down, connect a hose and submerge the hose in a pail of water after first blowing the air all out of the hose. If there are any gases in the cylinder other than anhydrous ammonia gases, bubbles will rise to the surface of the water, which shows that there are gases that should not be there, but if no bubbles appear, the ammonia is pure so far as "foreign gases" are concerned. A boiling-point determination will also be of some value and can be made with a good chemical thermometer.



INTERIOR OF THE COMPRESSOR ROOM OF A LARGE PACKING-HOUSE REFRIGERATION PLANT

A New High-Speed Gas-Engine Indicator

ABOUT two years ago the United States Bureau of Standards undertook the development of a special gas-engine indicator to meet certain special research requirements. Most of the high-speed indicators that have been developed commercially, involve the use of either a piston or a heavy diaphragm actuating a recording mechanism, which must be mounted on the engine. The problem to be met at the Bureau of Standards required an instrument that could be mounted on the engine which was inclosed in a concrete chamber and was inaccessible to the observer. The indicating mechanism must therefore either be placed outside the chamber containing the engine or be so designed that it could be operated from without. The high speeds and pressures prohibited the use of moving parts of any appreciable weight, since the inertia of these parts would interfere with the accuracy of the indication. The type of instrument that was finally adopted for development employed a very thin metallic diaphragm, one side of which is subjected to the pressure to be measured and the other to any desired pressure applied from without. Fig. 1 is a cross-section of that part of the apparatus which is mounted directly on the engine. The body of the instrument consists of a two-piece brass shell fitted to screw into a spark-plug hole and supplied with a water jacket. These two pieces, marked 1 and 2 in the illustration, are held together by bolts as shown, and can be readily separated for the removal or insertion of diaphragms. The diaphragm, which is of steel with about one inch effective diameter, is mounted between two slightly concave supporting plates perforated to allow the pressure to reach the diaphragm. Its thickness may be from 0.002 to 0.006 in. as required, and the range of motion is limited to about 0.01 in. The center portion of one of the supporting plates is electrically insulated in such a way that an electric circuit is made or broken as the diaphragm makes contact with this support or departs from it. Air under pressure from a convenient reservoir is admitted through the pipe marked "air," to the chamber above the diaphragm, and the pressure of the gases in the engine cylinder is transmitted to the chamber below the diaphragm. In the electric circuit outside the indicator proper are a battery and telephone receivers. To measure the maximum or or minimum pressure in the cylinder, air at an intermediate pressure is admitted to the indicator above the diaphragm. When the pressure in the cylinder becomes more than that above the diaphragm, the latter is forced up, making electrical contact with the electrode. Each time this contact is made and broken a click may be heard in the telephone receiver. The air pressure is then increased until the clicking just ceases, and this

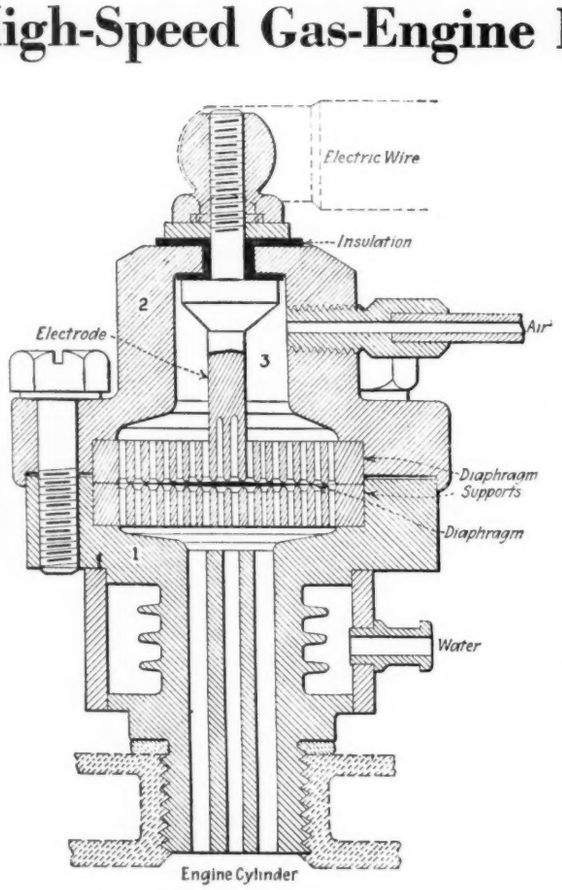


FIG. 1. SECTION OF NEW INDICATOR FOR HIGH-SPEED GAS ENGINES

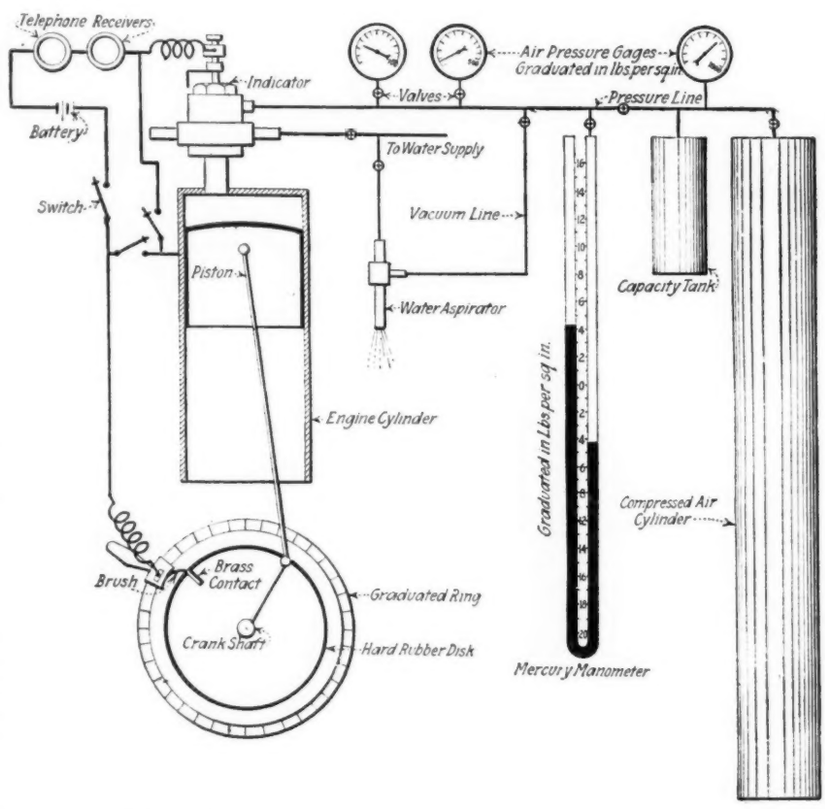


FIG. 2. DIAGRAM OF AUXILIARY APPARATUS FOR USE WITH INDICATOR

air pressure is noted as the maximum in the cylinder. The air pressure is then decreased until the clicking ceases again, and this pressure is noted as the minimum in the cylinder. To produce a complete diagram, a special one-point timer is mounted on the engine shaft. This timer is so designed that it

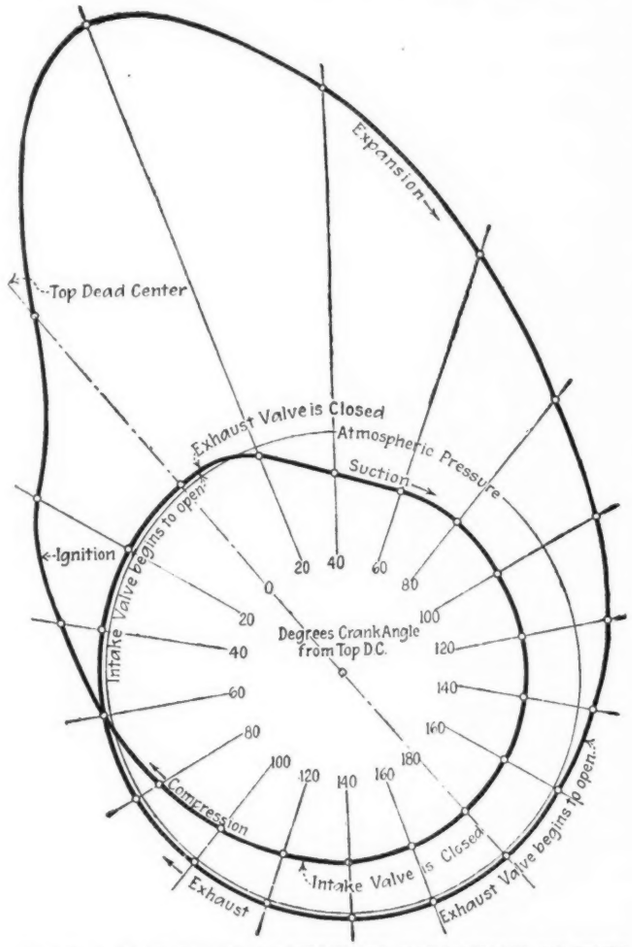


FIG. 3. POLAR DIAGRAM SHOWING VARIATIONS OF PRESSURE AT THE DIFFERENT CRANK POSITIONS

may be moved throughout the whole 360 deg. and is provided with a graduated ring so that its position may be accurately noted. The timer is connected in series in the electrical circuit with the telephone receivers and the indicator, so that the contact by the diaphragm will be heard in the receivers only when the circuit is closed through the timer. To get the complete diagram, the timer is set at a given point and the air pressure adjusted until the clicking just ceases, when the pressure is observed and recorded as the pressure at that particular crank position. The timer is then moved to another position and the same process repeated, until the pressures for a complete cycle at every ten or twenty degrees of crank angle have been recorded, and from these figures the diagram is constructed on the drawing board.

Fig. 2 shows the various connections of the external auxiliary apparatus. At the extreme right is shown the compressed-air cylinder to represent the supply of high-pressure air, while the *capacity tank* represents a small receiver to be used in accurate adjustment of the pressure. The pressures are measured by either one of the the two pressure gages shown or by the mercury in the manometer, the latter being used for measuring pressures slightly above atmospheric or for vacuums. The water aspirator shown is provided to produce a vacuum in the air line, when measuring pressures below atmospheric. The connection from the water-supply line to the indicator is to supply cooling water for the indicator jacket.

Fig. 3 shows a polar pressure diagram made by the help of this indicator. The radial lines shown represent the various crank positions, and the pressures are marked off on these lines from the center to any convenient scale. Through the points thus located a smooth curve is drawn, and the diagram is complete when the points at which the various valves open and close and the point of ignition have been located and marked.

Fig. 5 shows the same data plotted on a rectangular diagram. In this case horizontal distances represent crank angles from the top center and vertical distances represent pressures. The points are laid off in the same manner as in the case of the polar diagram and a smooth curve run through them

Fig. 4 shows a pressure-volume diagram which corresponds to the diagram that would be drawn by an ordinary engine indicator if it were possible to use such an instrument with a high-speed gas engine. In this case horizontal distances represent volumes and vertical distances pressures, as in the ordinary diagram.

This indicator requires that the indicating mechanism alone be mounted on the engine, the recording apparatus all being mounted at any desired distance. It is

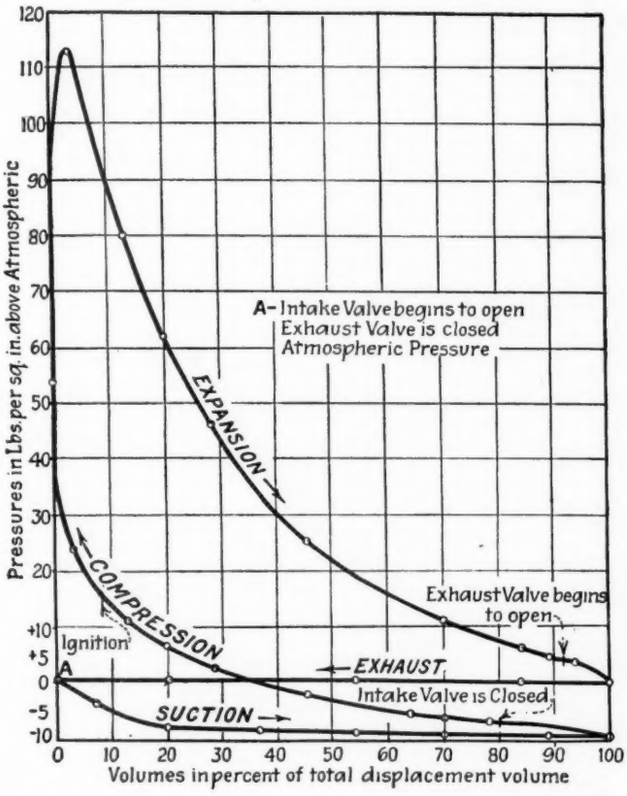


FIG. 4. PRESSURE-VOLUME DIAGRAM PLOTTED FROM INDICATOR OBSERVATIONS

sensitive to from 0.1 to 0.2 lb. per sq.in. over a pressure range of from 14 lb. below atmosphere to 500 lb. or higher above. It apparently has no limitations as to engine speed within the range encountered in practice and is apparently without appreciable inertia errors at any observed engine speed. It will give not only the

average pressure, but also the maximum and minimum pressures at any desired point or points in the cycle. It does not, however, permit the recording of a diagram of the pressures occurring in a single individual cycle, as is done by means of the optical devices in use.

In short the apparatus is adaptable to the measurement of cyclically varying gas pressures for a pressure range of from minus 14 lb. to plus 500 lb. and any speed likely to be encountered with sensitivity of from 0.1 to 0.2 lb. per sq.in., using a single thickness of dia-

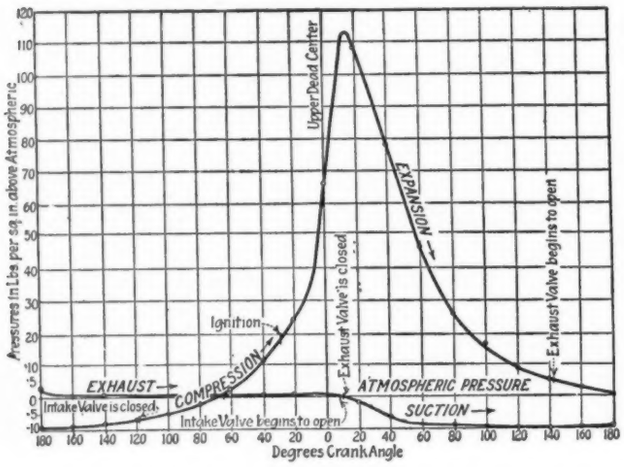


FIG. 5. RECTANGULAR DIAGRAM PLOTTED FROM INDICATOR OBSERVATIONS

phragm. Pressures up to at least 1,000 lb. can be measured with a somewhat thicker diaphragm and a correspondingly less sensitivity. The design and development of this instrument has been largely the work of Dr. H. C. Dickinson, of the Bureau of Standards in Washington.

The Bourdon Gage Spring

BY W. L. PARKER

Years ago M. Bourdon was engaged to repair the worm pipe of a still, which had become flattened. He endeavored to restore its original form with water pressure. In doing so the flattened tube tended to uncoil itself, and further experiments showed that the action of uncoiling might be applied in the construction of a pressure gage.

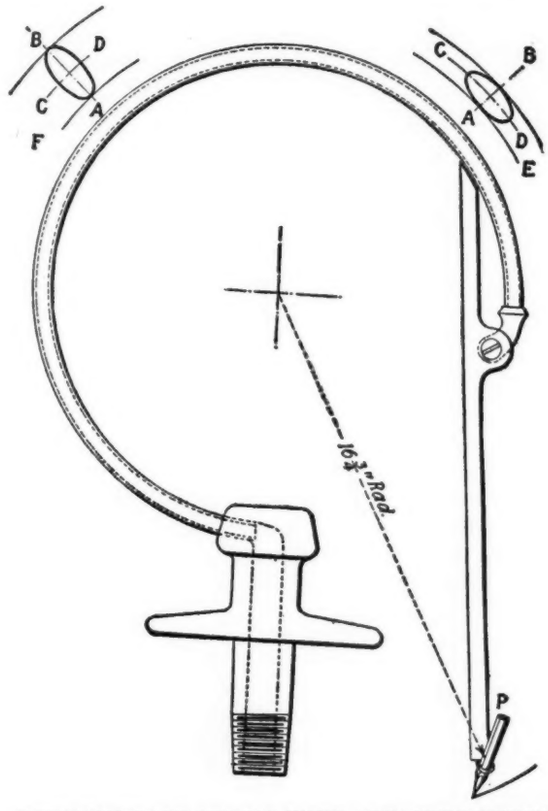
To understand the action of the Bourdon spring tube, it should be borne in mind that the tendency of pressure in a closed vessel is to increase the volume of it. It is often claimed that a curved tube of any cross-section will answer for a gage spring only that the flattened tube is more sensitive. This is in error. The flattened tube must be used. Pressure has no more tendency to straighten out a curved tube of circular cross-section than it has to curve a straight tube of circular cross-section. The reason is that in both cases the volume of the tube would be reduced. Pressure in a curved tube of circular cross-section puts the outer portion of the tube under tension and the inner portion under compression. The circular cross-section is maintained and the curved axis remains unmoved within the elastic limit of the tube.

In practice, for convenience, the short axis of cross-section *AB* is in the cylindrical surface containing the curved neutral axis of the tube, as shown by section *E* in the illustration. The effect of pressure in the tube is to force the sides apart or to lengthen *AB*, the short axis of cross-section, and to shorten the long axis *CD*. This increases the curvature of the cross-section and reduces the curvature of the tube, forcing its free end outwardly.

If the tube were flattened the other way so that the long axis of cross-section *CD* were in the plane of the tube, as in section *F* of the sketch, the effect of pressure, obviously, would be to force the free end of the tube inwardly. The limit of motion of the free end of the tube in each case would be reached when the cross-section of the tube became a circle.

From the foregoing it is apparent that excess pressure within the tube will force the free end outwardly or inwardly, depending upon the cross-section and its disposition in each case with reference to the plan of the tube.

The spring tube indicated by the drawing was taken from a well-known make of gage with an 8-in. dial and graduated to 30 lb. The coil of the tube was 5 in. in diameter. The cross-section was flattened as in the section *E* so that the major axis *CD* decreased $\frac{7}{8}$ in. and the minor axis *AB* increased $\frac{7}{32}$ inch. A pressure of 15 lb. moved the free end of the tube $\frac{1}{4}$ in. farther from the pipe connection; 30 lb. moved it $\frac{3}{8}$ inch. An extension with a pencil attached was secured to the



BOURDON GAGE SPRING WITH ATTACHED PENCIL

free end of the tube, as shown, and the pressure raised to 85 lb. The minor axis *AB* of the cross-section increased 0.02 inch. Measurements across the tube at right angles showed the curve of the tube to have increased in diameter $\frac{3}{16}$ and $\frac{1}{4}$ in. at the free end. The pencil *P*, 16¾ in. from the center of curvature of the tube, described an arc 3 in. long. The curve is believed to be an ellipse approaching closely to a circle.

Repairing a Shell-Type Transformer

How a High-Voltage Transformer Was Dismantled To Have a Number of Damaged Coils Replaced and How This Transformer Was Assembled After the Repairs Were Made.

By KENNETH A. REED

Maintenance Engineer, Interboro Rapid Transit Company, New York

KENNETH A. REED

DURING a severe lightning storm, a 33,000- to 2,300-volt bank of transformers was struck and one of them broken down in one section of the winding. The transformer was of the oil-insulated, self-cooled type, and the gases that formed in the tank were of sufficient violence to blow the top off and throw out a considerable quantity of oil. The customer was able to see the tops of all of the coils, and taking a chance on those which he could see were burned being the only ones that were damaged, he ordered new coils accordingly. The transformer had been taken to a storage warehouse as being the most convenient place for making repairs. There were no facilities whatever for handling heavy pieces of apparatus, and the most that could be said for the place was that there was plenty of room. Strong girders were found to have been used in the construction of the building, and it was decided to remove the core of the transformer from the case by means of a 10-ton chain block supported from one of these girders, as shown in Fig. 1.

After the core had been raised above the level of the oil, it was allowed to remain suspended there for several hours to permit as much oil as possible to drip back into the tank. This was a very important operation from a comfort point of view, because there is nothing quite so disagreeable and no liquid of which so small a quantity will spread over so large a surface as transformer oil. When the transformer was placed in the warehouse, it was left on rollers, which permitted getting the tank out of the way after the core had been raised high enough to clear the top casting. The core was then lowered to the floor, and wooden blocks, on the tops of which were cushions made out of heavy express paper, were placed under the sections of the secondary coils, as in Fig. 2.

After removing the terminal boards and main top casting, about ten inches of the laminations were taken off, and a long wooden beam eight inches square was inserted between the inside top of the coils and the laminations, the transformer being of the shell type. This beam was then picked up by the chain block, as in Fig. 3, and a portion of the weight of the core was thereby removed from the floor and the blocks under the sections of the secondary coils. The rest of the laminations were then removed, leaving the coils suspended on the beam and chain block.

When the sling was fastened to the end of the beam nearest to the damaged section, care was taken to leave sufficient room to move this section over far enough to allow another sling to be put around the beam. The weight of this end of the beam was then taken on the second sling by means of a block and fall, as in Fig. 4, which left the damaged section of the winding free on the extended end of the beam. The jumpers between the coils of this group were sweated off, the outside insulation removed and the coils separated. Fortunately, the customer had diagnosed the trouble correctly, and had ordered exactly the right number of new coils for making repairs.

Single coils were removed from the end of the beam, one at a time, until the damaged ones had been taken off, and it was a simple matter to substitute the new coils in place of the old ones and then reassemble the coils of this group. All the jumpers between coils were sweated on before the group was re-insulated, in order to make sure that no stray solder was left in the winding. By this procedure only one joint was left to be soldered when the group was connected to the other part of the winding. After placing proper insulation and circulating ducts between the coils, they were clamped tightly between boards that came to within about six inches of the top of the hole in the coils through which the laminations are built up. This space was then taped up and the clamps lowered another six inches, and so on until the entire sides were bound together. The process of removing this group from the undamaged part of the winding was reversed, and

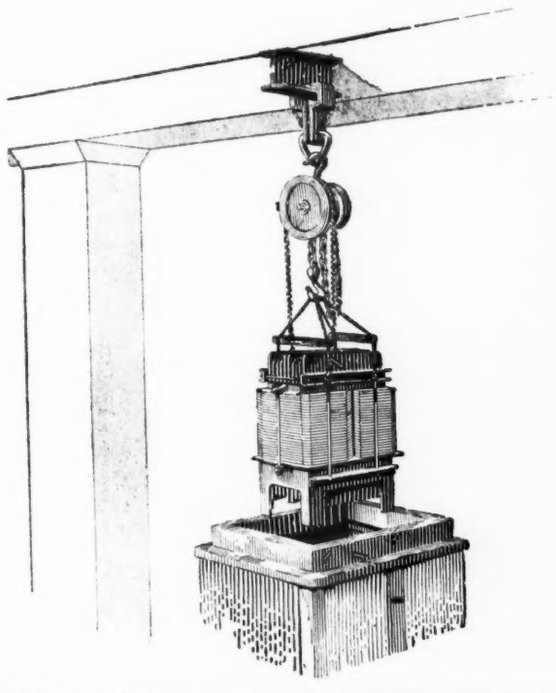


FIG. 1. TRANSFORMER BEING LIFTED FROM TANK

after binding the entire winding together, similar to the coils of the damaged group, sweating on the one jumper, insulating all joints and putting the outside box insulation in place, the core was ready for the building up of the laminations.

The bottom casting which supports the laminations was now put in position, and the blocks with cushion

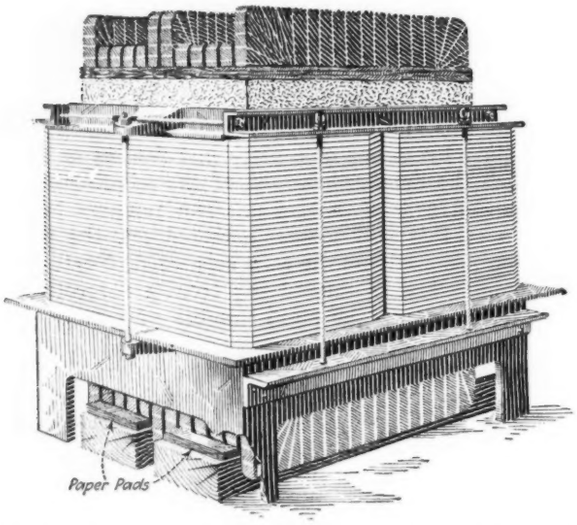


FIG. 2. METHOD OF SUPPORTING SECONDARY COILS

tops were shoved under the secondary coils, as was the case when the transformer was dismantled. After about twelve inches of iron had been built up, a small timber was laid on top of the laminations and a jack tightened

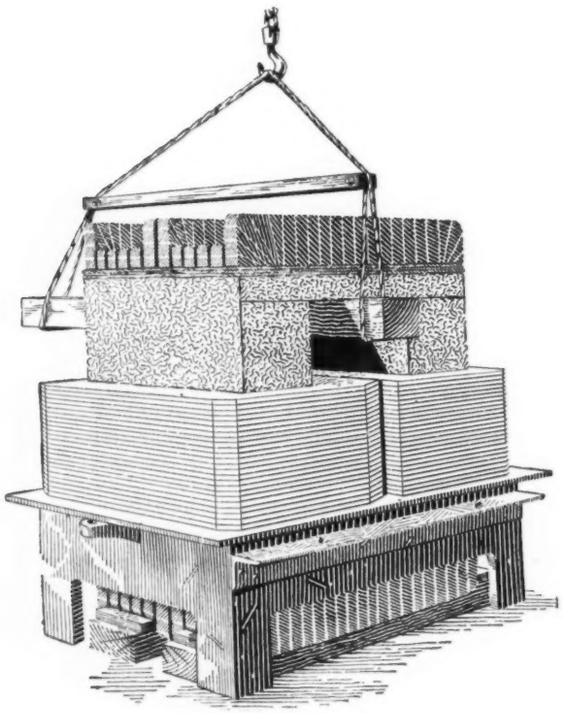


FIG. 3. WEIGHT OF THE COILS SUPPORTED ON SLING

up between it and the top beam for the purpose of pulling the laminations down tight, in order that none of them would be left over. This was continued until about eighteen inches of iron was in place, when the through beam was removed and the top casting used to pull the laminations down tight. This was repeated for about every six inches of iron until all the laminations were installed, and the top casting, terminal blocks, etc., were put in place permanently.

During the time the transformer was being rebuilt, there were several very rainy days, and as there was no heat in the warehouse, the windings absorbed a great deal of moisture, which required that the transformer be thoroughly dried out before being put back in the tank. It might be added that whenever such repairs are made to any high-voltage oil-insulated transformer, drying out is almost invariably necessary, regardless of weather conditions, before the transformer is replaced in service. The most convenient method of drying out a transformer in the field, and the one used in this case, is by short-circuiting the secondary winding and applying low voltage at normal frequency to the primary, provided a suitable range of voltage is available. This condition as a rule, is easily met at a central-

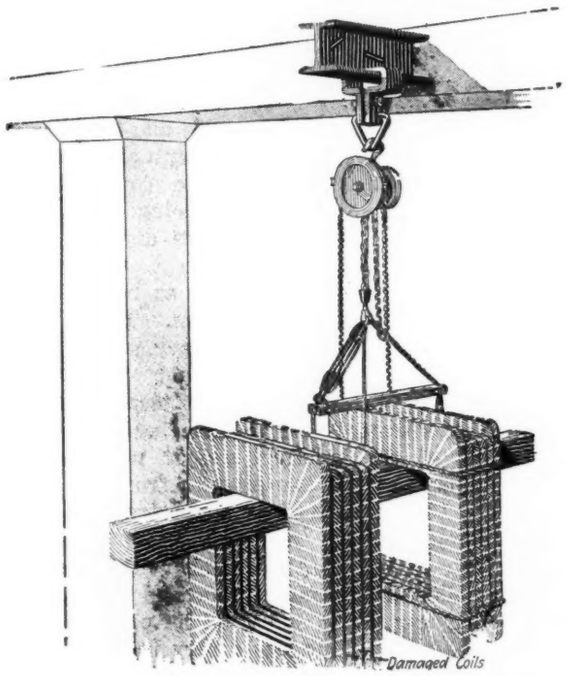


FIG. 4. HOW THE DAMAGED COILS WERE REMOVED

station plant, because it is usually possible to secure as many 10-kw. 2,300- to 220-110-volt lighting transformers as might be desired, and by series-parallel combinations the proper voltage can be obtained. Before exciting the transformer, thermometers were placed at what might be expected to be the hottest points in the primary and secondary coils, and in order to avoid heating the transformer windings too rapidly, an ammeter was placed in the secondary circuit and the current kept at a safe value until the temperature stopped rising. This precaution was necessary because as a general thing under such conditions, there is a tendency for the coils to sweat, and serious damage may be done in a very short time.

When the temperature had stopped rising, the applied voltage was raised slightly, and the temperature of the hottest point brought up to approximately 90 deg. C., where it was maintained for about three days and nights. During this time both the day and night shifts were required to keep a log showing the temperature

registered by each of the thermometers every fifteen minutes. The current was then cut off, and insulation tests made with a "megger." The readings obtained showed the transformer to be thoroughly dry and safe to go back into service. It was accordingly replaced in the tank and securely bolted in position and the oil, which had been dehydrated and tested, was poured in, the tank having been repaired in the meantime.

Shortly after the current had been applied to the primary terminals, with the secondary short-circuited, and the temperature had risen to an appreciable degree, the belief that the winding was defective became prevalent among some of the men who had been working on the transformer. This was due to the fact that the transformer appeared to be smoking to such an extent that, had such been the case, the winding would have been burning up. The "smoke," however, was only a vapor caused by the oil on the laminations being vaporized by the rapid rise in temperature. Such a condition is quite likely to occur with any oil insulated transformer that has been removed from the tank and its temperature raised somewhat higher than normal; and to one who had not observed such a case before, it would seem very serious. The vapor was very similar to that which may be seen rising from the "breather" on a bearing of a large, high-speed turbo-generator.

Flue-Gas Temperature and CO_2 as a Guide to Furnace Operation

With Special Reference to Oil Burning

By CHARLES C. PHELPS

WHILE test data on combustion are important and should be as nearly accurate as possible, some simple method of checking furnace performance is necessary for everyday economical operation in the boiler room. A study of test data shows that the excess of temperature of the flue gases above that of the boiler room and the percentage of CO_2 in the flue gases give a guide to combustion conditions, and may be determined quickly enough to be of help in regulating the furnace action.

TABLE I. RELATION OF FLUE-GAS TEMPERATURE TO LOSS FROM DRY FLUE GAS

	Case 1	Case 2
Flue-gas temperature T deg. F.	350	650
Boiler-room temperature t deg. F.	50	50
$T - t$	300	600
CO_2 in per cent	12	12
Loss in dry flue gas, per cent of total heat in fuel	10.4	20.8

It is a known fact, corroborated by reference to tables of chimney losses, that with a given fuel and with a constant percentage of CO_2 in the flue gases, the proportion of the fuel's heat which is lost up the chimney in the dry products of combustion is directly and exactly proportional to the difference between the flue temperature and the boiler-room temperature. For instance, in the example given in Table I, representing a certain fuel, it will be noticed that the heat loss in the dry chimney gas is twice as great in the second case, in which the temperature difference is twice as great.

It is also a fact, likewise readily verified, that when the flue temperature remains constant the heat lost up the chimney in the dry products of combustion is *almost* exactly in inverse proportion to the percentage of CO_2 in the flue gases, as shown in Table II. It will be noticed that in case 4, Table II, where the percentage of CO_2 is half as great as in case 3, the loss is about twice as great. The discrepancy is so small that for all approximate calculations it may be assumed that the loss is exactly in inverse proportion to the CO_2 when the temperature does not vary. If the percentage of CO_2 had been 4 instead of 6 (one-third of 12), the dry chimney-gas loss would have been 60.7 per cent, or approximately three times as great.

TABLE II. RELATION OF CO_2 TO LOSS FROM DRY FLUE GAS

	Case 3	Case 4
Flue-gas temperature, T deg. F.	650	650
Boiler-room temperature, t, deg. F.	50	50
$T - t$	600	600
CO_2 in per cent	12	6
Loss in dry flue gas, percent of total heat in fuel	20.8	40.8

From these statements of facts it is apparent that the dry chimney-gas loss with a given fuel is approximately proportioned to the ratio $\frac{T - t}{per\ cent\ CO_2}$. This ratio, therefore, may be used as a guide for the operation of the furnace.

The temperature of the flue gas is affected by the deposit of soot and dirt on tubes or in flues and of scale within the boiler, by the condition of the baffling, arches, etc., and by the rate of driving. Therefore, fluctuations in the flue temperature are usually small and infrequent in comparison with the fluctuations in the percentage of CO_2 and this is particularly true at fairly constant driving rates. Under such conditions the percentage of CO_2 by itself becomes a reliable index of loss in the dry chimney gases. For this reason a CO_2 recorder alone, without a pyrometer, is often used to keep records of the heat lost up the chimney, although a recording pyrometer is also highly desirable.

TABLE III. TYPICAL OIL-FUEL HEAT BALANCE

		Per Cent.
1.	Loss due to heat carried away in dry flue gases	14
2.	Loss due to superheating moisture formed by burning hydrogen in oil	7
3.	Loss due to incomplete combustion (CO and hydrocarbons)	0.1
4.	Loss due to evaporation of moisture in fuel	0.1
5.	Loss due to heating of moisture in air	0.4
6.	Loss due to radiation and unaccounted for	3.4
7.	Heat absorbed by boiler (including vaporizing of fuel)	75

The excess air is entirely responsible for the so-called CO_2 loss, which is the heat loss involved in heating the excess air from the temperature of the boiler room to that of the flue gas. The factors first mentioned—that is, those indicated by stack temperatures—are very largely under the control of the boiler-room foreman, who should be responsible for clean boiler surfaces, etc. On the other hand, proper air supply is entirely under the control of the fireman and the percentage of CO_2 is the only reliable guide to him in adjusting the ratio of air to fuel, which is so vital in securing combustion efficiency.

It so happens that in oil burning the loss in the dry

chimney gases is the only loss that fluctuates to any great extent. In Table III are shown the various losses as they occur in the heat balance of a typical oil-burning boiler. Loss (3) should be nonexistent or negligible in quantity in a well-designed and properly operated plant. Loss (5) is likewise unimportant. Losses (2) and (4) are dependent upon the composition of the fuel and are

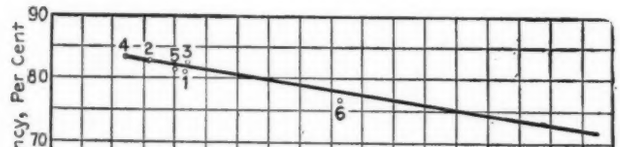


FIG. 1. DRY CHIMNEY GAS INDEX $\frac{T-t}{CO_2}$ WHICH INDICATES BOILER EFFICIENCY

Plotted from test on a 604-hp. boiler using oil of 13.2 deg. Be. with an average heating value of 18,200 B.t.u. per lb. as fired.

Test No.	1	2	3	4	5	6	7
Efficiency, per cent	81.1	82.8	82.4	83.3	81.5	76.4	75.8
Smoke	None	None	None	None	None	None	Light haze
Carbon dioxide, per cent	12.2	13.4	13.3	14.3	14.2	13.3	12.1
Temperature of flue gases, T deg. fahr	365.3	397.5	409.1	406.2	429.0	477.1	537.5
Temperature of boiler room, T deg. fahr	88.7	86.6	84.4	85.2	87.3	86.7	84.4
(T—t)	296.6	310.9	324.7	321.0	341.7	390.4	453.1
$\frac{(T-t)}{\text{Per cent } CO_2}$	24.3	23.2	24.4	22.4	24.0	29.3	37.5

fixed in amount, hence they cannot be appreciably reduced by the fireman. Loss (6) may vary slightly, but in a well-designed plant there is little the operator can do to reduce it.

Loss (1) is usually greater than all the others combined. Neglecting the slight fluctuations in the other losses, it is apparent that as the dry chimney-gas loss increases, the efficiency will decrease by the same amount, and vice versa. Referring to Table III, an increase in item (1) to 19 per cent would result in a decrease in item (7) to 70 per cent and a decrease of (1) to 9 per cent would result in an increase of item (7) to 80 per cent. Thus it follows that under the conditions found in oil-burning practice the factor $\frac{T-t}{per\ cent\ CO_2}$ becomes almost as good a guide to over-all boiler efficiency as to chimney losses. Applying this line of reasoning to the data furnished from tests on a certain plant and plotting Fig. 1 therefrom, it is seen that this factor is indeed a remarkably good working index of boiler and furnace efficiency, although not a mathematically perfect one. In the plot the horizontal ordinates represent the factor $\frac{T-t}{per\ cent\ CO_2}$ and each point represents the value of this ratio for one test. The vertical ordinates represent the efficiency in per cent. The points are nearly all on a straight line, which shows that the boiler efficiency has a simple relation to the factor $\frac{T-t}{per\ cent\ CO_2}$. If the reader has data on several efficiency tests under his own conditions, he can easily make up a chart like Fig. 1 for his particular fuel and boilers.

The writer has examined a great many tests by this method and has found it to check up almost invariably. When it does not, the usual explanation is that when the average CO_2 is used instead of the average losses corresponding to CO_2, there is likely to be a discrepancy, which is especially noticeable when the CO_2 fluctuates over a wide range.[1] For momentary values of the factor $\frac{T-t}{per\ cent\ CO_2}$, the points on an efficiency index chart such as Fig. 1 should lie almost exactly on a straight line. Each point noted in Fig. 1 represents an average

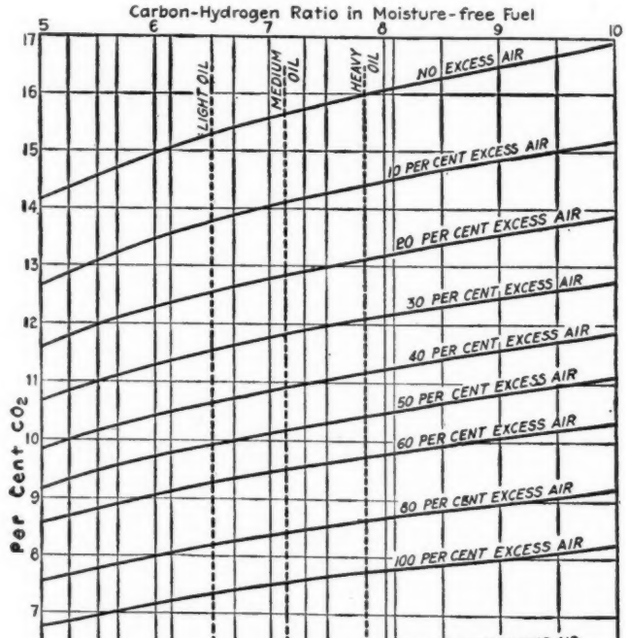


FIG. 2. PERCENTAGES OF CO_2 CORRESPONDING TO VARIOUS PERCENTAGES OF EXCESS AIR FOR DIFFERENT FUEL OILS

Carbon-Hydrogen ratio is $\frac{C+0.4\,S}{H}$ and *per cent available hydrogen* is $\frac{100\,H}{H+C+0.4\,S}$ where *C*, *H* and *S* represent the percentages of carbon, hydrogen and sulphur respectively in the oil when freed from moisture.

APPROXIMATE COMPOSITION IN PER CENT OF OILS REPRESENTED BY DOTTED LINES

	C	H	S	N	O	H_2O
Light oil	84	13	0.8	0.2	1	1
Medium oil	85	12	0.8	0.2	1	1
Heavy oil	86	11	0.8	0.2	1	1

value of CO_2 and temperature over a seven-hour test, hence the very close alignment is all the more remarkable.

From the foregoing it is apparent that a pyrometer and CO_2 recorder of the continuous type furnish all the information required to conduct what practically amounts

[1]See article by the author, page 297 *Power*, Feb. 24, 1920.

to a perpetual efficiency test under operating conditions. The CO_2 recorder alone serves in this way as a guide to efficiency in many plants where the flue temperature remains fairly uniform. At any rate the information which is most vital in keeping the greatest single item of loss down to the minimum is furnished by the CO_2 recorder.

Fig. 2 shows the percentages of CO_2 that will be recorded when various proportions of excess air are used in burning fuel oil of various compositions. Each curve represents a different percentage of excess air. The upper curve represents the theoretical quantity of air for complete combustion; that is, 0 per cent excess air. The vertical scale on the left margin represents the percentages of CO_2. The lower horizontal scale represents percentages of hydrogen in various hydrocarbon fuels. This represents only the percentage of hydrogen in the combustible matter in the fuel and does not include the hydrogen in moisture in the fuel. The upper horizontal scale expresses the composition of the same range of fuels in different terms; namely, the ratio of carbon to hydrogen, not including the hydrogen in the moisture in the fuel.

Corrections for Sulphur in the Fuel

Sulphur in the fuel will burn to sulphur dioxide (SO_2) and will be absorbed by the absorbent in the CO_2 recording machine, adding to the apparent CO_2 percentage just as though it were CO_2. Hence, sulphur must be taken into account if it is present in appreciable quantities. The easiest way to take account of the sulphur is to multiply its percentage by 0.4 and add this result to the percentage of carbon, thus treating SO_2 as though it were CO_2. The factor 0.4 is used because the volume of SO_2 in the flue gas produced by a given weight of sulphur is just about four-tenths as great as the volume of CO_2 produced by the same weight of carbon. Air contains 20.9 per cent by volume of oxygen, and if all this were converted into CO_2 the percentage of the latter in the flue gas would also be 20.9. Some oxygen, however, is required for converting the hydrogen in the fuel into water-vapor, and the nitrogen accompanying this oxygen appears in the flue gas. Therefore, the greater the percentage of hydrogen in the fuel, the less will be the percentage of CO_2 in the flue gas. All the curves in Fig. 2 will illustrate this fact. As a consequence, it would seem that with fuel oil a much lower percentage of CO_2 should be carried than with fuel low in hydrogen—for example, anthracite coal or coke. This, however, is not usually the case for the reason that oil can generally be consumed with a much smaller proportion of excess air, because of the ease of obtaining a thorough mixture of the air and fuel during the process of atomization. The amount of excess air that must be used in oil burning will be found to be larger in some cases than in others owing to the fact that some boiler furnaces are not designed to withstand the extremely high temperatures that accompany minimum air supply.

Variables Which Affect Amount of Air Required

Such economical adjustments of the air supply as those mentioned cannot, of course, be maintained, especially with oil burners, without keeping continuous records of the percentage of CO_2. Every little change in the constantly changing conditions of operation will necessitate readjustment of the air supply. Such variable factors, for instance, as change of direction and velocity of wind, atmospheric temperature, barometric pressure, percentage of humidity, demand for steam, temperature of furnace, quantity of dust on tubes or in flues, amount of scale in boiler, degree of superheat, condition of furnace lining and baffling, and many others, have an effect, often a sudden effect, on the quantity of air and fuel required.

The usual rule in burning oil is to cut down the air supply until a "light haze" appears at the top of the stack. From the test data accompanying Fig. 1, it may be observed that the only test in which this "light haze" is noted showed the lowest efficiency of the series. While this is not sufficient evidence that a "light haze" means poor efficiency, it suggests that it may not be a reliable guide to the best operating conditions.

A boiler furnace, whether coal- or oil-fired, cannot be set in advance to meet varying operating conditions, as, for instance, the valves of an engine are set. Continuous readjustment is necessary. Sometimes these adjustments must be made every few minutes and sometimes every hour or even at longer periods, depending entirely on the nature of the load and the conditions of operation. It is generally conceded that in no other part of the power plant is the personal element a greater factor than in the boiler room. Certainly in no other part are there greater opportunities for savings than are possible in connection with fuel conservation, and high CO_2 is the key to fuel saving. There is no substitute for the personal element, but fortunately it pays handsomely to employ human brains, guided by efficient CO_2 instruments, to keep the air and fuel in balance at all times.

Losses Due to Low CO_2

To see just what losses are involved when we neglect the CO_2 factor, assume an oil corresponding to that marked "medium" on Fig. 3 and that this oil has a heat value of 18,600 B.t.u. per pound of combustible. If we used 200 per cent excess air, the percentage of CO_2 would be five, and at this figure, with 650 deg. F. stack temperature and 50 deg. boiler-room temperature, the loss of heat up the chimney in the dry gases alone (not including the losses in the moisture) would equal 35.3 per cent of all the available heat in the fuel. Plants are actually producing as bad results as this and even worse. Taking the same temperature difference, if 40 per cent excess air is supplied the dry gas loss is reduced to 16.6 per cent, while if operation were possible at 10 per cent excess air the loss would drop to 12.9 per cent.

Fuel conservation and particularly fuel-oil conservation is one of the most important economic problems of this day and generation. The best way to conserve it in the boiler room is to utilize as large a proportion as possible of its heat in doing useful work—that is, in evaporating water in the boiler—and to waste as small a proportion as possible up the chimney by keeping the volume of the exhaust gases as small as possible with the aid of CO_2 instruments and by keeping the temperature of the flue gases as low as possible.

The electric-power generating equipment on the British battle cruiser "Hood" consists of an unusual variety of apparatus. Eight generators are provided, each of which can supply either alternating or direct current as may be desired. Four of these generators are driven by reciprocating steam engines, two by geared high-speed impulse turbines and two by eight-cylinder Diesel oil engines.

Nathaniel A. Carle—A Progressive in Power Plant Construction

Mr. Carle has inspected practically all of the large turbine plants of the country with the object of determining the efficiency of these prime movers under various operating conditions. Observations on these trips combined with his own wide experience in the installation and operation of these units and as chairman of the Prime Movers Committee of the National Electric Light Association, lead him to the opinion that 30,000 kw. 1,800 r.p.m. 60 cycles and 35,000 kw. 1,500 r.p.m. 25 cycles can be considered for the present as the maximum standard sizes of single-shaft, single-barrel units. Moreover, during the past year considerable information has been obtained from the operation of these large units as well as from some of the smaller machines, with the result that steps are being taken to bring about helpful co-operation between the designers and the men under whose charge they operate.

TO BECOME chief engineer of a large power corporation in charge of its diversified power system is close—very close to the top. Nathaniel A. Carle, Chief Engineer of the Public Service Electric Company of New Jersey, has attained this position. A forceful personality combined with pronounced administrative ability and power of analysis early marked him as a leader of men, and from the time when he left college to enter the industrial engineering field until today, his progress has been steady and sure.

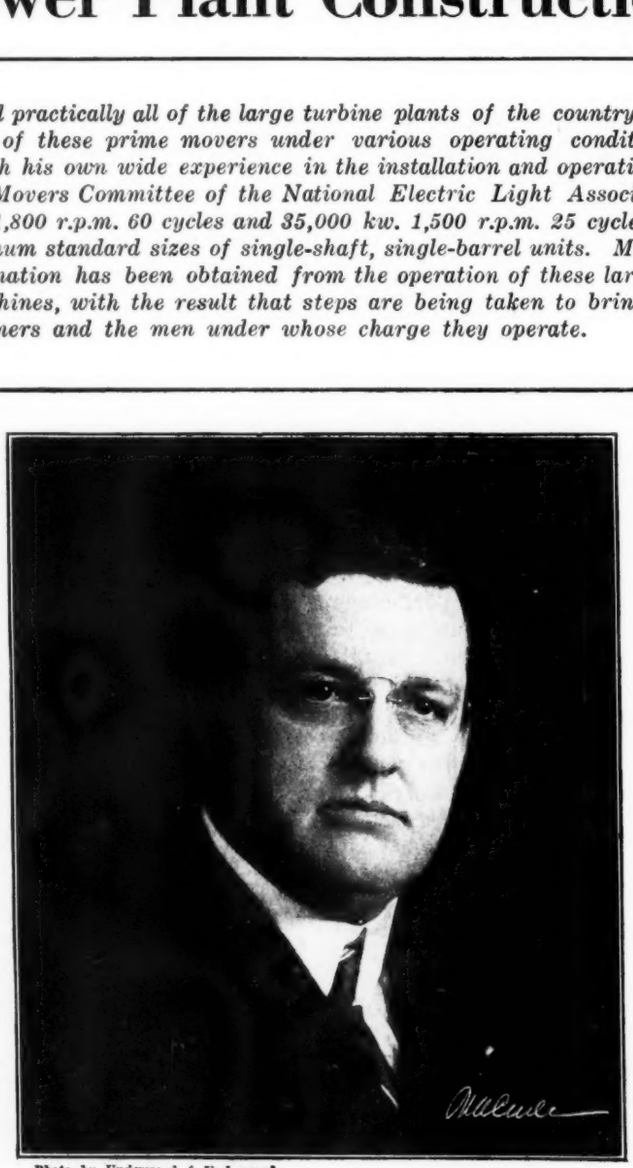


Photo by Underwood & Underwood.

Mr. Carle's activities are not confined to supervision of one of the largest public power systems in the country, but he also is an active member in a number of engineering societies and is at present serving on twenty-three committees. He has done a great deal of investigation work with turbines, and as chairman of the Prime Movers Committee of the National Electric Light Association, much of his time has been occupied with problems confronting that body.

The use of pulverized fuel in large power plants and increased efficiency in the boiler room are hobbies with Mr. Carle, and much research work has been done by him, with the result that the Public Service Electric Company is getting ready to install an experimental outfit at the Marion Station within the near future for the utilization of this fuel. If this proves successful, it will be applied to the smaller stations first.

His work in connection with increasing the efficiency in the boiler room has done much toward making the plants of his company safer and more economical. He is a strong advocate of placing an experienced high-priced man in charge of the boiler room, as a large percentage of the plant saving depends upon the performance of the boilers. While a believer in high pressure for maximum efficiency, he is opposed to extremely high pressures until a more comprehensive knowledge of boilers and their auxiliary apparatus and their ability to carry such pressures has been gained.

Mr. Carle was born in Portland, Ore., May 28, 1875. When he was six years old his parents moved to Seattle, Wash., and it was here that his education began. He received his elementary education in the public schools, followed by a course in mechanical engineering at Leland Stanford, Jr., University, from which he graduated in 1898. While at the University, Mr. Carle, always a lover of the great outdoors and extremely fond of athletics, played on the varsity football team for three years. He was also initiated to membership in the Beta Theta Pi fraternity and the honorary engineering society of Sigma Psi.

Following graduation he accepted a position with the Silver Bow Mining Co., which was operating at Juneau, Alaska. He worked underground as a miner, for practical mining knowledge, and in the latter part of 1898 he was employed by the Canadian Rand Drill Co. at Sherbrooke, Quebec. He remained there until 1900, then resigned and went to New York City, where he became associated with Westinghouse Church Kerr & Co. He supervised and directed many large jobs while with this company, including the installation of a large power plant in the Back Bay Station of the New York, New Haven & Hartford Railroad at Boston. He was field engineer on the construction of the Kingsbridge power station, which had the distinction for many years of

being the largest and most economically operated power plant in New York City. While credit is due to the engineers in charge of the operation of the plant, yet it stands out as a monument to the thoroughness and ability of the engineer in charge of installation and construction, for efficiency and economy in operation cannot be gained where installation is faulty. Following the completion of this work Mr. Carle was made first assistant to the superintendent of construction on the Long Island Power Station of the Pennsylvania R.R. at Long Island City and later of the entire electrification of the railroad.

In 1906 he was sent to Denver, Col., as engineer in charge of work on large power-plant construction at the coal fields and in the electrification of the railroad between Denver and Boulder for the Northern Colorado Power Co. His handling of these jobs made such a favorable impression on the officials of the Northern Colorado Power Co. that in 1907 he was induced to become vice president and general manager of the company.

He resigned from the Northern Colorado Power Co. in 1909, returned to Seattle, his boyhood home, and opened offices as a consulting engineer. He later became associated with the Puget Sound & Dredging Co. His work finally attracted the attention of the Public Service Electric Co. of Newark, N. J., and he accepted the position of chief engineer. His ability was put to the test at once. He was called upon to reorganize and enlarge the engineering force of the company and accomplished this so thoroughly that he has since been in charge of the entire engineering and construction work.

The company operates eighteen generating stations with a capacity of 270,000 kw., and 100 substations are supplied with power over the system of 850 miles of overhead and underground transmission circuits operating at 13,200 and 26,400 volts. During the war over one hundred and fifty plants, engaged in war work, were supplied with power.

Despite the fact that his work claims a great deal of his attention, Mr. Carle finds time to take an active interest in a number of engineering societies, including the American Institute of Electrical Engineers, Engineering Council, American Society of Civil Engineers, American Society of Mechanical Engineers on Power Test Codes Committee, Association of Edison Illuminating Companies, National Electric Light Association, chairman of Prime Movers Committee and vice chairman Technical and Hydro-Electric Section, American Metric Association, and the American Electric Railway Association.

Washery Sludge Burned in Pulverized Form at Seattle

THE Puget Sound Power and Light Co. at Seattle, Wash., includes, among its public utilities, a district steam-heating plant of 4,100 boiler-horsepower, which for nearly two years has been fired with pulverized high-grade lignite. The results shown have been so favorable that all those connected with its operation are enthusiastic advocates of this form of combustion.

When the United States entered the war, it early seemed probable that the Federal Government would place restrictions upon the use of fuel oil on the Pacific Coast and that consumers remote from the oil fields would be forced to look to other forms of fuel. Faced with a shortage of oil, Stone & Webster, managers and engineers for the company, undertook a careful study of the possibilities of utilizing the local grades of coal in such of its Seattle plants as were then dependent upon oil. Early in the spring of 1917 one of the smaller boilers at the steam-heating station referred to was set aside for experimental purposes and an extensive series of tests conducted, using practically all grades of coal locally obtainable, in which the thorough practicability of combustion of these coals in the pulverized form was fully demonstrated.

Pulverization was finally decided upon as most favorably meeting the local conditions. It was particularly advantageous at Seattle as affording means for efficient utilization of a 200,000-ton sludge dump at the Renton mine just outside the city limits. The adoption of pulverized fuel had also the important advantage of leaving the existing oil-burning equipment immediately available in efficient form. Conversion to pulverized fuel was accordingly made by Stone & Webster the following year.

The station referred to, which is known as the Western Avenue Station, faces on Western Ave. and extends through to Railroad Ave. on the harbor front. It is about two blocks from the center of the retail shopping district. Originally, the station was designed as an ice plant. The boilers, many of which were installed twenty years ago, were set with low furnaces and with aisle space so narrow as to make a satisfactory stoker installation impracticable. Although the small furnaces would undoubtedly have curtailed efficiency for any fuel, while burning oil the lack of aisle space involved no serious interference with operation. A change to coal, however, in any other form than pulverized, without rebuilding the entire plant, would have called for hand firing, which not only would have been most difficult from a labor standpoint, but would have restricted the consumption to high-priced coal.

The present boiler plant totals 4,100 hp. in rated capacity, made up of four 300-hp., three 400-hp., one 500-hp. and two 600-hp. boilers, all of the B. & W. type. One of the 600-hp. units was installed at the same time as the pulverized-fuel preparation plant and was accordingly set with front headers eleven feet above the boiler floor. All the other boilers, as already referred to, have low furnaces, with headers set only about seven feet above the floor.

The coals mined in the vicinity of Seattle are subbituminous in nature, closely bordering upon lignite, and require washing in preparation of all the smaller sizes. At the Renton mine, washery sludge, regarded as a total waste, had been accumulating for years. This material carries about 25 per cent moisture and has an average heat value of about 7,300 B.t.u. A typical analysis on the dry basis is approximately as follows: Volatile matter, 37 per cent; fixed carbon, 38 per cent; ash, 25 per cent; sulphur, 1 per cent. This washery

sludge is also small in size, about 50 per cent passing through a 10-mesh screen, rendering it totally unfit for use on any existing form of mechanical stoker.

As originally reclaimed from the dump, the sludge carries such a high content of clay that its adhering qualities would render it practically impossible of handling in any ordinary form of conveying apparatus. By combining some washing with the sluicing process used in carrying the sludge from the dump, a large part of this clay is removed. Regular washing tables are now being installed on which the clay will be completely removed.

The Coal-Preparation Plant

The plant that converts the raw coal into pulverized coal consists of three main divisions: (1) The raw-coal handling system, comprising raw-coal storage bunkers, crusher, crushed-coal bunkers and interconnecting conveyors; (2) the drying plant, comprising the driers and dry-coal bunkers with conveyors feeding the driers and delivering the dried coal to the bunkers; (3) the pulverizing plant, comprising the pulverizing mills with their feeders and the necessary conveying system delivering to the pulverized-coal bunkers.

The Raw-Coal Handling System

Limitations of space made it impracticable to provide sufficient fuel storage within the station building. The desired additional raw-coal storage was accordingly installed on a vacant lot adjoining one of the company's electrical substations and immediately across Western Ave. from the steam-heating plant. The three raw-coal bunkers erected for this purpose are of heavy wood construction, lined with galvanized iron and have a total capacity of about 700 tons. The bunkers are served by a standard-gage double track on an overhead trestle from which hopper-bottoned cars discharge.

From the bunkers the coal is fed through double rack-and-pinion gates to a 20-in. feeder belt, which conveys the coal to a single roll-type crusher where, when lump or run-of-mine coal is used, it is crushed to about one-half inch size. A bypass chute is provided around the crusher, so that the smaller-sized coal can be fed directly from the feeder belt to the conveyor belt leading from the crusher to the raw-coal elevator. The conveyor belt from the crusher is a combination incline-horizontal belt, 20 in. wide, which, carried through a tunnel under Western Ave., delivers the crushed coal to a double-strand, fixed, continuous-bucket elevator, steel incased, which elevates the coal 75 ft. and discharges it onto a double-strand steel flight conveyor for distribution to the crushed-coal bunker.

All the raw-coal handling equipment has a capacity of 75 tons per hour; with buckwheat coal 90 tons has been handled. The crushed-coal bunker, which is of reinforced concrete, has a capacity of about 350 tons.

The Drying Plant

To convey the coal from the crushed-coal bunker to the two driers, two apron feeders are provided, each served by a 5-ft. by 10-in. opening at the bottom of each of the two V-section hoppers formed beneath the crushed-coal bunker. Each feeder is provided with a vertical sliding rack-and-pinion gate to regulate the flow of coal. Both feeders discharge into a common chute, which is equipped with a flopper gate and steel-plate diaphragm so that either feeder may discharge coal into either or both of the driers. A screw feeder immediately beneath each apron feeder handles the drippings from the return side of the feeder and delivers these drippings into the feeder discharge chute which branches to feed the two driers. Mechanical agitators are installed in the branch chutes to prevent clogging. On account of the high silt content the sludge in the wet state is of particularly sticky consistency and requires positive mechanical movement at every point.

The two driers are of the indirect-fired, rotary type, with settings especially designed for maximum heat utilization. The cylinder dimensions are respectively 5 ft. diameter by 52 ft. long and 6 ft. diameter by 52 ft. long. Pulverized coal is used for the drier fuel. The heat absorbed through that part of the drier cylinder within the heating chamber reduces the hot-gas temperature to about 500 deg. F. The gases finally leave the drier at a temperature of about 270 deg. F. The coal is discharged from the driers at a temperature of about 240 deg. F.

Induced draft for the driers is supplied by two turbine-driven fans. These fans discharge into insulated cyclone separators located above the roof of the preparation plant proper, where all but the finest of dust drawn from the drier with the exhaust gases is collected for return to the system. This collected dust is delivered by screw conveyor to the dry-coal elevator into which the main drier is discharged. The gases from the cyclone separator pass to an exhaust chamber, where, before being finally allowed to escape to the atmosphere, they are washed for removal of the small amount of dust remaining. Salt water from the harbor adjacent to the plant is used in this washer. The proximity of the plant to the business district of the city necessitates special provisions for dust prevention.

From the driers the coal is discharged over magnetic separators for removing tramp iron such as spikes, bolts, nails, and into the dry-coal elevator. The dry-coal elevator is of the single-strand, fixed-bucket type, steel incased, 62 ft. between centers, and is provided with weighted take-ups to compensate for temperature changes met in such service. The dry coal discharged at the top of the elevator is distributed by screw conveyor to the dry-coal bunkers, which are of reinforced concrete and have a capacity of about 150 tons.

The coal as it reaches the dry-coal bunkers still carries a small percentage of moisture which for a time continues to be given off as steam. To provide for the escape of this steam atmospheric vents, suitably drained, are installed. It is found in practice that approximately one per cent additional moisture is given off by the coal in the bunkers and removed by this means. Other vents are also provided in the dry-coal elevator casing to remove such moisture as may be liberated between the driers and bunkers.

From the dry-coal bunkers the coal is fed to the pulverizing mills.

The Pulverizing Plant

The pulverizing equipment consists of three 42-in. Fuller-Lehigh mills of a capacity about 3½ tons per hour each, pulverizing to 80 to 85 per cent through a 200-mesh screen and one five-roll, high-side Raymond mill adjusted to a capacity of about four tons per hour for delivery of a slightly coarser product. The pulverized coal from these mills is delivered by screw conveyor into a continuous-bucket, single-strand, centrifugal discharge elevator with reinforced-concrete casing. This

elevator discharges into a screw conveyor distributing the coal to the pulverized-coal bunkers which supply the boiler and drier furnaces. The bunkers supplying the boilers provide capacity for about one-half day's normal operation and are of reinforced concrete, except in the case of two bins where it was impracticable to employ this construction.

All pulverized-coal elevator and conveyor casings are of dustproof construction as are the connections from both Fuller and Raymond mills. Further, to insure absolute dustlessness within the preparation plant that part of the pulverized-coal system, including the Fuller mills, is operated under a slight vacuum. The small exhauster employed for this purpose is arranged to discharge directly to certain of the boiler furnaces. The vent from the Raymond mill separator is similarly disposed of.

The Combustion Equipment

The pulverized-coal feeders are of the screw-conveyor type, each operated by a variable-speed direct-current motor, thus providing complete control of the coal feed by simple rheostat adjustment. From the feeders the pulverized coal is picked up by air under a pressure of about five to six ounces and delivered to the burners. The air supply is furnished by turbine-driven blowers delivering to a central blast duct beneath the pulverized-coal bins, from which branches are taken off to the individual feeders and burners. Air regulation is had by means of valves in the air-feed lines.

The burners, which were developed by the Puget Sound Power and Light Co.'s steam superintendent, are extremely simple in construction, consisting merely of a special mixing elbow delivering the aërated coal to the furnace horizontally through a straight pipe nozzle in such manner as to induce with the fuel jet the greater part of the additional air required for combustion. On account of the low setting of the boilers it was necessary to place the burners below the main boiler floor to provide the required space for combustion of the fuel before reaching the heating surface.

The ash resulting from combustion varies in composition from a fine powder to slag; some is deposited as dust on the tubes and back of the bridge wall, some escapes with the flue gases, but the major portion falls to the bottom of the furnace as coarse sand and rather soft clinker. The dust accumulation on the tubes is removed by mechanical soot blowers supplemented by a hand lance once or twice a day as required. The ashes and clinker from the furnace are raked out at regular intervals, quenched with a hose, conveyed by hand-dump cars, are elevated by electrically operated skip hoist to an overhead ash bunker from which they are discharged to trucks for final disposal.

Operation

Burning the pulverized washery sludge as described, boilers are regularly operated on continuous loads of 150 per cent to 175 per cent of the rated capacity. The station as a whole has readily carried steam-heating loads of 6,000 boiler-horsepower and has shown over-all net operating efficiencies, as determined from steam production per pound of wet sludge, fully equal to those obtained with mechanical stokers utilizing the better grades of coal of this district, of larger size and carefully prepared. Boiler maintenance has been markedly reduced. With oil firing, tube failures under heavy loads were far from uncommon. Since the adoption of pulverized coal, such failures have been practically unknown.

The success of the installation, the simplicity and efficiency of combustion, the flexibility in capacity, attained with a fuel which by any other available means it would have been impossible to utilize at all, quite naturally converted the operating organization and officials of the Puget Sound Power and Light Co. to enthusiastic advocates of pulverized fuel. Nevertheless, they do not look upon pulverization as a universal panacea for the high cost of fuel, but urge that every situation be viewed as a special problem and that all the affecting conditions be carefully studied before attempting any decision as to the best form for combustion in any particular case.

Refrigerating Effect of Natural and Artificial Ice

By John H. Ryan

The comparative merits of natural and machine-made ice is an old story in the ice business and was started by the natural-ice men claiming that their ice would keep the ordinary box colder than would the machine-made ice. Thermometers placed in the boxes bore them out in their argument, as the refrigerators always showed two or three degrees colder with the natural ice.

In 1913 I was chief engineer in a combined brewery and ice plant in New England where competition was keen in the ice business. We bought an ordinary household refrigerator that held approximately one cubic foot of ice and put a recording thermometer in the side of the box and then put the box in one of the ale-storage cellars kept at a constant temperature of 50 deg. F. We left the empty box with all doors open for two days to be sure it was the same temperature as the cellar. The ice to be used was set to one side of the ice-storage anteroom for the same length of time so that the natural and artificial ice would be at the same temperature. We put 48 lb. of ice in the box to test with and made three tests of each kind of ice alternately. The elapsed time from when the recording thermometer started to drop from 50 deg. F. to when it came up again to 50 deg. F. was slightly over five days, and there was less than twenty minutes difference in the time of all the tests. The longest elapsed time was with one of the natural-ice pieces, but so also was the shortest time, and we decided it a draw.

In Boston the next year I had an opportunity to observe both kinds of ice in a grocer's refrigerator, and discovered the "joker" to be in the manner in which the ice is placed in the box. Natural ice gets more handling and breaking before placing in the customer's box, and it is so rough that it does not make a closely packed mass. The air can circulate all around each cake, which cools the air because there is such a large ice surface in contact with it. With manufactured ice the surfaces are so smooth that they lie close together and freeze into a solid mass and the only surface offered to the air is the outside of the frozen mass, which is small compared to the rubble surface of natural ice. In this case the manufactured ice lasted longer while not cooling the boxes so low. By instructing our drivers to pile the can ice checkerboard fashion we could meet the temperatures obtained with natural ice, and increased our sales.

Rules for the Safe Operation of Steam Engines and Turbines

By E. E. CLOCK
Chief Inspector, Turbine and Engine Department, The Fidelity and Casualty Co. of New York

Starting the Engine

No engine should be started until it has been thoroughly inspected since its previous run. Inspect for loose nuts, keys, fittings, main belt, flywheel, receiving pulley, governor and governor belt. This should be done at the end of the run to allow time for adjustments or repairs. This applies to all auxiliaries necessary to the operation of the engine.

Removing Water

Be sure the engine is warmed up and the cylinder and steam pipes, exhaust pipe, receiver and coils, and the jackets, are free of water; if the receiver is of cast iron be sure the relief valve is set well within the safe pressure limits and that it is of ample capacity to free the receiver of all steam the high-pressure cylinder may be able to give it under any or all conditions of sticking or broken valves.

Starting Machinery at Distance

If the engine is belted to the machinery in the plant so that machinery is started at a long distance from the engine, the engine should not be started until a warning is given by ringing a gong or otherwise.

Governing Point

When the engine is coming up to speed, the governor should be watched closely for any sticking or sluggishness. Closely note its full ability to hold the speed down to not over four per cent overspeed at no load. Stand by till the engine has taken a load and as long a time afterward as time will permit; the engine should not be left alone till it is running satisfactorily.

Engine Running Alone

The engine should not at any time be left out of the sight and hearing of someone capable of getting it under control in case of accident.

Lubrication

The governor should not be handicapped in the control of the engine by bad lubrication. Sediment in combination with graphite and bad or gummy oils causes the packings rings to stick in the piston. Use graphite sparingly in engines provided with self-adjustable pressure plates or balance rings or any steam surface that is provided with water-grooved packing.

High-Test Oils in Low Temperatures

Never use a high-flashpoint oil on a low-temperature engine; 600-test oils should not be used on engines carrying less than 125 lb. pressure unless there is superheat. It is not advisable to use the same cylinder oil on the low-pressure cylinder that is used on the high pressure.

Driving Belts

All of the surface of the belt should be kept in contact with the pulley and not allowed to dry out; neat's-foot oil or castor oil will usually produce proper surface contact. Do not allow belts to become soaked with lubricating oil.

Speed-Limit Device

Engines running under very widely fluctuating loads should be provided with a speed limit device independent of the governor.

Turbines

Turbines must be guarded against water entering with the steam. Therefore use extra care in warming up and draining. Frequently inspect the regulating gear and know that the speed-limit device is proven to be in order by frequent testing. Turbines should be immediately taken out of service upon failure of the speed-limit device. Atmospheric relief valves must be provided and kept free to open quickly and easily without subjecting the low-pressure end of the turbine to undue pressure.

Relief Valves

Bleeder or extraction type turbines should be provided with relief valves in the bleeder or extractor stage to relieve the turbine of all the steam that comes through the first stage, even with the loss of many blades or buckets. Also provide a non-return valve to prevent return of steam from bleeder line. These valves must be frequently tested to insure reliability.

Tachometer and Circuit-Breakers

No turbine should be operated without a reliable tachometer or frequency indicator; and all turbines and engines feeding to a common busbar should be provided with proper circuit-breakers and, if direct current, should be provided with reverse-current relays.

Testing Safety Devices

All safety devices should be tested regularly and the result of the test entered on a log sheet provided for the entering of all tests, including safety valves, relief valves, relays, speed limits, etc., with the time and date of tests duly entered above the signature of the engineer making the test.

Flywheel

Be sure the flywheels are operated with an ample margin of safety on strength as well as speed, using the formula

$$\frac{1680}{\textit{Diameter in Feet}} = \textit{Safe Speed.}$$

Steam Mains

Be sure the steam mains are so arranged that the drainage or condensation will flow toward the engine and are properly intercepted by a suitable separator and trap. Be sure the trap is so located that it may be watched.

Pockets

Be sure there are no sags or pockets in the steam main that would allow water to accumulate and go to the engine in slugs.

Gagpots

Gagpots or dashpots on governors should be kept free from gum or dirt accumulation, as this prevents the Corliss type of governor from going to the low or safety limit and the flywheel or shaft governor from reaching limits necessary for the full control of the engine under a sudden release of load.

Gaging the Governor

Never under any circumstances gag the governor to prevent it from shutting down under overload or low steam without placing a man at the engine to remain until the governor can be restored to the safety condition.

EDITORIALS

Sawmill Drive in the Pacific Northwest

THE lumber industry in the Pacific Northwest is reaching proportions that are greater than the pioneers dared to hope. Every day sees a demand from some quarter, either for new markets altogether or for new uses for available timber. Just now the lumber industry is probably larger in point of demand and output than ever before in its history. Considering Washington alone, 7,250,000,000 feet passed out of that state in 1918, and it is likely that the 1919 cut will show a gain despite the fact that the serious labor disturbances of that year reduced output. But this year the great mills of this remarkable Northwest country are passing timber at an astounding rate. The world seems to be drawing heavily upon our timber.

Now, in an industry that has become so large, one naturally looks for big things mechanically, and is not a bit disappointed when visiting the large camps and mills on Puget Sound, in Oregon and in Northern California. In fact, one is rather surprised. It is not uncommon to see a man at a keyboard in a screeching, busy mill, pressing the many keys each of which operates a spinning saw, causing it to lower itself and cut a board to a certain length or to remain uplifted, allowing the board to pass and be cut by other innumerable saws in the row, all at the discretion of the operator. One feels the might of the country and the industry when standing back and watching the little Japanese laborers on the carriages where the grotesque mechanical "niggers" grip the huge timber and flop it over on its side like the man in Childs' window flops the griddle cakes. It is to feel that you are in the midst of big things when watching the tugging cranes pick up a whole flat-car of logs, each two to ten feet in diameter, and roll them into the mill pond.

And the big thing about it is that it is all a power job—yes, every operation from cutting and transporting the great trees to delivering the finished lumber to the shipping docks or cars. There are some modern, high-grade, high-pressure steam engines and apparatus up there in the echoing woods that would gladden the hearts of Corliss and Watt. There are engines, turbines, air compressors, pumps, electric generators and what not in the mills that would turn an uninitiated engineer in search of variety and problems green with envy. The mechanical engineer, the power engineer, of a large, modern lumber company has a man's-size job.

And it begins to look as though he and his manufacturing associates are about to introduce high-tension, hydro-electric current into their field on a large, varied and interesting scale. This is by no means the general practice. The thought is, How general is it likely to become? Distance of lumber camps from transmission lines is a factor; but it is obvious that the cheapest construction will do to connect the two, for the work is of necessity of a temporary character. More specific and detailed technical information on the application of electricity to lumber camp and sawmill work is needed.

Another Reason for an Operating Code

COMPARISON of instruction pamphlets that usually accompany all new apparatus from the manufacturers' shops will often reveal considerable difference in matters of detail respecting the functioning of similar equipment. Were these instructions to be followed explicitly, a station that happened to contain two or more makes of apparatus for like service would find itself employing an equal number of methods in their operation. What usually results is a compromise in operating practice that, in the opinion of the management, best meets the local conditions.

This is all very well as long as everything runs smoothly, but as a rule manufacturers will stand back of their guarantees only to the extent that their operating instructions are carried out. Let anything happen to the apparatus where these are being deviated from, and there immediately arise grounds for possible controversy.

This is just an additional point in the argument that has previously appeared in these columns for the establishment of an operating code for central stations or large industrial plants along the lines of the present Power Test Codes, and which it is understood is now being seriously considered by the Prime Movers Committee of the National Electric Light Association.

A Needed Reform in Marine Boiler Law

WELL back toward the middle of the last century, Congress enacted laws for the regulation and inspection of steam vessels navigating the waters of the United States. It is proposed to amend that portion of the law which provides for the allowable working pressure in boilers. A bill known as Senate Bill Number 574 has been introduced and referred to the Senate Committee on Commerce.

The present law provides that the working pressure shall not produce a "strain" of more than one-sixth of the tensile strength of the plate when the longitudinal joints are single-riveted, but that this allowable pressure may be increased twenty per cent if the "longitudinal laps" are double-riveted, provided the rivet holes are fairly drilled and not punched. This section of the law was in its day a reasonable attempt to insure safety, although the use of the word "strain" where, obviously, "stress" is meant, shows that the authors were not familiar with engineering. A hard and fast rule based on even the best of engineering knowledge at that time would be out of date today. How much more so is a rule whose authors probably were well meaning but apparently not engineers?

Suppose we have a boiler built with a joint efficiency of fifty-six per cent and another with an efficiency of eighty-four per cent. Obviously, the second boiler is half as strong again as the first, assuming both to have the same diameter and thickness of shell, yet the old

rule would allow both the same working pressure. If the rule would make the first boiler safe, then the second is handicapped, while if the rule is reasonable for the second, the first boiler is close to the danger line if not over it. Surely, it is time for an amendment of this rule.

The proposed amendment provides that the allowable pressure shall be determined by the rules of the Board of Supervising Inspectors. Under the law as it now stands, this board makes and issues rules and regulations for the construction and inspection of steam boilers, hulls, etc., and these rules are from time to time amended by the board in the light of current engineering progress. It would seem only a logical step to intrust this board with authority to fix the thickness of the boiler shell according to modern engineering practice instead of by an arbitrary rule which is sadly out of date.

Grounded Neutral

TO GROUND or not to ground the neutral of alternating-current systems and to what extent grounding should be carried, provided it is decided to ground the system, is a much discussed question on which about as many different opinions are held as there are persons discussing it. This was evident at a recent meeting of the Association of Iron and Steel Electrical Engineers in Pittsburgh, for after over two hours' deliberation on the question of grounded neutral, no definite decision was reached. However, the trend of the discussion would indicate that if the system is large, such as those of central stations, the neutral should be grounded, while the smaller systems should be operated insulated from the ground.

Three elements are of primary importance in the operation of any electrical system; namely, protection to life and property, continuity of service, and protection to apparatus. Of the three, protection of life and property is of first importance. It has become general practice to ground the neutral low-voltage circuits when exposure to higher potentials exists, such as when the low-voltage circuit is supplied from a step-down transformer. Low-voltage alternating-current circuits of one-hundred and fifty volts and less are usually of the single-phase type, supplied from transformers and to a very large extent used for lighting purposes. Power circuits are generally operated at four-hundred and forty volts and above. If a three-phase four-hundred-and-forty-volt circuit is connected star with the neutral grounded, there will exist from either phase to ground a potential of two-hundred and fifty volts. Although it is not generally recognized, statistics show that on circuits of four hundred and forty volts and less the greatest danger from fatal shocks exists. Of ninety-nine fatal electrical accidents occurring in England during the period 1915 to 1918, sixty-nine happened on circuits having a potential of four hundred and forty volts and less. It is doubtful if any of these fatalities were due to voltages higher than two hundred and fifty, since the voltage to ground on any of these circuits was not above the latter value. There is apparently a distinct advantage in operating such systems ungrounded, since when the neutral is grounded a potential exists to ground that can cause a fatal shock, yet it is not in general considered as such by workmen. Unless the system is kept insulated, the advantage gained by insulating the neutral is lost and a more dangerous condition is created. On potentials above five hundred and fifty volts workmen in general will take proper precautions in handling such circuits whether they are grounded or ungrounded, consequently there is little or nothing to be gained, so far as safety to life is concerned, in operating the higher-voltage systems ungrounded.

Continuity of service and protection of equipment are so interconnected that one cannot be considered without the other, since if the apparatus is not properly protected it will be subjected to abuses, the results of which will be reflected in frequent shutdowns of the equipment for repairs. If the neutral is grounded. a ground on any leg of the circuit will cause a short-circuit and the motor or circuit is made inoperative until the defect is repaired. This, in some cases, may mean serious interruption or inconvenience in the manufacturing process. From this point of view grounding the neutral is a distinct disadvantage, especially where means are provided and put into effect to keep the system insulated at all times.

Where systems are very large, and few industrial plants come within this category, the electrostatic capacity is high enough to set up very heavy surges in the system in case of an arc to ground. These surges are liable to break down the insulation of equipment. In such cases, if the neutral is grounded the circuit breaker will be tripped when the arc first occurs and the apparatus relieved of excessive voltages, which might cause insulation failure at the time of the disturbance or at some future time. "How large should the system be before it is advantageous to ground the neutral?" is apparently the question around which centers operating power systems with or without the neutral grounded. Many central-station systems are operating with the neutral grounded, while on the other hand industrial plants are operating with the neutral insulated. It is on this question that engineers in charge of industrial power systems have an interesting field for investigation.

Turning Waste Into Profit

EACH year there is produced in the lumber industry of the Pacific Northwest thousands of tons of wood refuse from the mills, called hog fuel. This, ordinarily, is a nuisance and is disposed of by burning either in furnaces constructed for the purpose or in a great pile a short distance from the mill. Its fuel value is high—dry, it averages about 8,500 B.t.u. per pound.

This part of the country has little coal other than some lignite, which is confined chiefly to a small area in Washington. Fuel oil, upon which the steam plants chiefly depend, comes from California and, like fuel oil in the East, is now very high in price. Tests have been made with hog fuel under steam boilers and the results are so favorable, in view of existing fuel conditions, that there is being developed a market which promises to take at a profitable price much that will be produced in many localities. An article elsewhere in this issue gives particulars about the boiler performance with and market for this waste fuel. The problem, by the way, is an engineering one and the sawmill engineer is the one charged with the solution.

If the proposed Congressional junket at the expense of the Government is carried out it will cost Uncle Sam quite a sum. Somebody has suggested, however, that it may be worth the cost to have Congress adjourn.

CORRESPONDENCE

B. T. U.'s Versus Kilowatt-Hours per Ton of Coal as Measure of Efficiency

In the March 9 issue R. S. McBride's comments on page 386 should be of interest to everyone. It is no fault of Mr. McBride's that he went wrong, but rather of the United States Geological Survey, Division of Power Resources. The data on which the comments were made were so presented that he had a right to assume that the fuels used in all cases were for power production only, and therefore the efficiency with which fuel was used was proportional to the kilowatts per ton of coal. One of the tables presented in the article is reproduced here:

TABLE I. EFFICIENCY OF POWER PRODUCTION IN TEN STATES

Results for four months, February, March, April and July, 1919, as compiled by U. S. Geological Survey, Division of Power Resources. Computed on the basis of four barrels of oil equals one ton of coal and 20,000 cubic feet of gas equals one ton of coal.

State	Current Produced Millions of Kw.-Hr.	Fuel Used Thousands of Tons of Coal or Equivalent	Efficiency Kw.-Hrs. per Ton
New York	1,124	1,420	792
Pennsylvania	958	1,610	595
Illinois	784	1,311	597
Ohio	776	1,282	605
Massachusetts	403	533	756
Michigan	390	497	787
New Jersey	308	459	671
West Virginia	237	321	738
California	222	310	716
Indiana	213	585	364
Average	.....	....	662

On the strength of this information Mr. McBride derived the only possible conclusions that could be made if depending only on the information furnished by the table. The trouble is not with the information given, but that it tells only half the truth, and the deductions in themselves are correct from the point of view of the commentator, but are far from representing actual facts. After presenting the table referred to Mr. McBride comments as follows:

> This first comparison shows that some states, such as New York, Michigan and Massachusetts, secure twice the current production per ton of coal as is obtained, for example, in Indiana. This at once raises the question as to why there are such great differences.
>
> All of the ten states which are the largest users of power lie in the northeastern quarter of the country except California. It is of interest, therefore, to notice particularly the results in some of the Southern and Western States. South Carolina, Georgia, Alabama and Kentucky similarly computed in comparison show, respectively, 417, 481, 324 and 493 kilowatt-hours produced per ton of coal used. Thus the average for these four seems to be less than for the states which are larger power producers, but in general the average is not as low as Indiana, already mentioned. Some of the Western States seem to be the worst offenders in the way of low efficiency, for in North Dakota and Montana the average current production is only approximately 150 kilowatt hours per ton, or less than one-quarter of the average in the states which are the largest users.

Kilowatt-hours per ton is the standard of measurement of efficiency, the only thing possible from the information furnished by the Division of Power Resources, and the conclusion that there are public-service corporations whose efficiencies are in the ratio of 5 to 1 are borne out by the material considered. Granting all this, the only thing that can be said is that the conclusions are misleading and the facts in the case, if properly reported, would be very different.

In large manufacturing states with large cities, power plants, in order to satisfy large power demands, are made up of large units operated condensing, and the output is power measured only in kilowatts. In this class of power plant the efficiency is and will be proportional to the kilowatt-hours per ton of coal, and this standard may be applied to this class of power producer without modifications.

In agricultural states where there are very few large cities, and with a large number of small towns scattered throughout the state, the power demand is not large, although important. Stations are made up of relatively small units, the larger of these operating condensing only part of the time and the smaller units most noncondensing. These plants, besides producing power, furnish heat in the heating season and in some cases make ice during the summer. When the winter and summer are fairly balanced, they furnish heat in winter and refrigeration in summer, the latter service consisting chiefly of making ice with exhaust steam in an absorption system.

In the state of Indiana, where heat is furnished throughout the season, using practically all of the exhaust for four months and perhaps some live steam as well as three months of the season, the electric output is simply a byproduct, costing very little as regards fuel. This point should be emphasized particularly in the case of North Dakota and Montana set forth as the "worst offenders," where the kilowatt-hours per ton is 150. In these states the heating season starts in September and ends in May and a temperature of 30 to 40 deg. below zero is common. During six months, no doubt, the plants use live steam as well as the exhaust available from power production, and during the remaining two months 75 per cent of

the exhaust is utilized. Measuring their efficiency by kilowatt-hours per ton of coal would be like measuring the dog by a piece of its tail.

Coming back to Indiana, in this state a great number of public-service plants are furnishing heat. Some of the larger ones are equipped with condensing and non-condensing units so as to make use of the exhaust. For about four months they utilize all the exhaust, and during two months of the four most of them use live steam, making power a byproduct instead of the primary product.

Farther to the south, in fact even in Illinois, there are plants furnishing heat, ice and power, and in localities fortunately placed they may and do use exhaust steam all the year around. In such plants the kilowatt-hours per ton of coal could not be expected to compare, say, with the same unit measurement of a large power plant operated condensing and equipped with economizers, superheaters and large turbine units. But when the comparison is made on the basis of true efficiency, thermal efficiency, which is the ratio of the output to the input in B.t.u., the results will be all in favor of the small plant making use of its exhaust steam.

Plants being compared on the basis of kilowatt-hours per ton of coal may show efficiencies in the ratio of 5 to 1, and the same plants compared on their thermal or actual efficiency can show the reverse; that is, the plant that showed five times as many kilowatt-hours per ton of coal may be actually only one-fifth as efficient.

A well-equipped power plant situated in a zone of the best coal produces a kilowatt-hour on less than two pounds of coal. Plants less fortunate as to coal and average equipment require between two and three pounds of coal. Although a rate of two pounds of coal per kilowatt-hour is excellent practice, the figure will indicate that less than 12 per cent of the heat in the steam is utilized. Granting a boiler efficiency as high as 75 per cent, the over-all thermal efficiency of such a station will be $0.12 \times 0.75 = 0.09$, or 9 per cent.

Now the diversified power plant furnishing heat and power in North Dakota or Minnesota uses, say, ten pound of coal per kilowatt-hour of output and utilizes 75 per cent of the heat in the steam the year around. The chances are that it will use 80 per cent of the total heat in the case of an eight months' heating season. Grant that the boilers are operated at 60 per cent efficiency over-all the year around, the station thermal efficiency will in that case be $0.75 \times 0.60 = 0.45$ or 45 per cent.

Summing up, the first power plant is producing a kilowatt-hour on two pounds of coal and the year around is operated at 9 per cent thermal efficiency. The second plant produces a kilowatt-hour on ten pounds of coal and operates the year around with 45 per cent thermal efficiency. The ratio of kilowatt-hours per unit of coal is as 5 is to 1 and the ratio of thermal efficiency is exactly the reverse, the first being operated at 9 and the second at 45 per cent efficiency. It will be seen why kilowatt-hours per ton of coal cannot convey the actual facts unless some detailed explanation is given. Using the ratio of the output of the station in B.t.u. to the input would give the true station efficiency and would not require any explanation.

Reports of this kind are good to have, but the data should be complete and not misleading. Let us hope that the Division of Power Resources of the United States Geological Survey, seeing the interest taken in their work, will favor us in the future with more complete information or adopt as a standard of measurement of station efficiency, B.t.u. instead of kilowatt-hours per ton of coal.

HENRY MISOSTOW.

Chicago, Ill.

Circumferential Cracks in Crankshafts

The shaft of an oil engine which was 19 in. diameter at the portion where the flywheel was located, had developed a crack that could be plainly seen, and although the engine was kept in operation, the engineers were cautioned to watch it carefully and report if the crack showed signs of becoming worse. In the meantime the builders were notified to send a man to examine the shaft and advise what to do. I was sent to look into the matter.

The owners would not allow me to drill into the shaft for fear of weakening it still further. How to determine the depth of the circumferential crack was a problem that had to be solved. I had no precedents to follow and had never read anything on the subject. The engineers on the job had tried drop black mixed with kerosene, but could not determine the depth from the story it told. I lay awake a few hours that night and did some tall thinking. I had an idea that rubbing Prussian blue mixed with kerosene into the crack (which extended for possibly two-thirds the circumference at the root of the fillet where it turned upward toward the larger part of shaft upon which the flywheel was keyed) and then using three gasoline torches to heat the shaft, would give a pretty fair indication of the depth of the crack from the amount of coloring matter that would ooze out. This idea was carried out, but it resulted in but little matter oozing out. Then I let the shaft cool while plenty of Prussian blue was applied, as I assumed that the contraction would absorb some coloring and that upon heating the shaft again it would ooze out.

However, I found that but little coloring matter was absorbed, as but a very little oozed out—and about the same amount at each heating of the shaft. This convinced me that the crack was not deep, and I set up a turning rig and took a light cut from the shaft. It was as I suspected and a $\frac{1}{32}$-in. chip removed all signs of the crack. The engine was run regularly, and two years later the crack again appeared, but now, after 6 years' operation, it is no worse. No doubt an internal strain in relieving itself, slightly cracks the shaft. The only thing possible to do under such circumstances is to watch the crack carefully, keep notes regarding its conditions and check up regularly, and upon indications of its getting worse, get a representative of an electric-welding company to look it over and advise if they can cut a trench through the crack and afterward fill it up properly with the same metal as the shaft.

This, to my mind, would be the most logical thing to do. Forging the shaft would require its removal and sending away, which would result in the loss of money while the engine was down. I hardly think that reforging the shaft could be done without distorting it so that it would require re-turning to a smaller diameter at the bearings and crankpins to true it up. This would necessitate new bearings all around. Hence, I consider reforging of a shaft illogical and altogether too costly. Electric welding and building up looks more logical.

New York City. D. L. FAGNAN.

Suggested Damper Arrangement

Many things are still done as our forbears used to do them, because they are not deemed important enough to require consideration. For instance, take the seting of the damper construction where the damper slides in a cast-iron frame. Considerable leakage occurs where such dampers are mounted in the orthodox way, as shown in Fig. 1. There is generally a slot provided in the brickwork where the top of the flue touches the

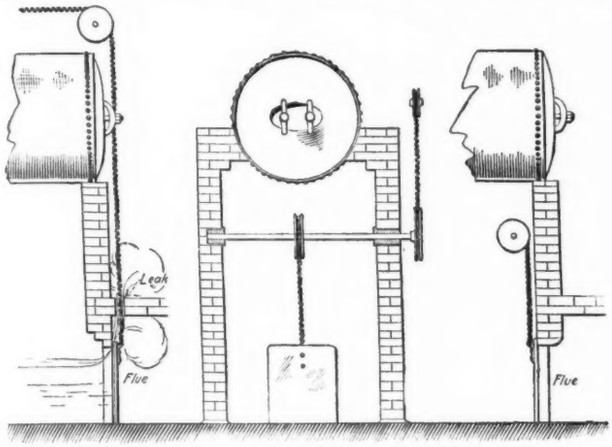


FIG. 1. ORIGINAL SETTING

FIG. 2. SUGGESTED DAMPER SETTING

back wall of the boiler setting, through which slot the damper may be placed in the frame or removed from it. This slot is sometimes closed by placing loose bricks over it, leaving a hole through which the operating chain passes.

I have seen many installations where the air leakage at this point was considerable and might easily have been avoided by placing the dampers on the inside of the wall, Fig. 2. The chain leading from the damper is attached to the periphery of a grooved sheave, the diameter being such as to allow full travel of the damper with about three-quarter revolution of the sheave. This sheave is secured to a shaft which turns in simple bearings mounted in the side walls of the boiler setting. One end of shaft passes through the side wall and has a sheave of the same size attached, on the periphery of which the chain holding the counterweight is attached. With this arrangement there will be very little leakage through the bearing.

Another advantage is the renewal of the operating chain in front of the manhole. O. JANZEN.

Half Way Tree, Jamaica, B. W. I.

The Need of Competent Engineers

In the April 6 issue of *Power*, page 561, an illustration is given of an incompetent engineer. I would like to say a few words on the subject of incompetent engineers.

I was in a large steam plant in this locality a short time ago installing a Corliss engine, and observed that the boilers were blowing off almost continually. I went to the boiler house for a short time and watched the firemen work. I asked one why he kept the boilers blowing off so often and he said that the furnaces had 80 sq.ft. of grate surface and that there was about 50 sq.ft. covered with fuel. I asked why the chief did not take off one or two boilers, and the reply was that it would make it easier for the firemen and that the chief didn't care because some bad coal had been received about a month before and as a result the steam went down. The chief had said it would not go down again if he had to put on all the boilers, as it was better to let them blow than shut down. This engineer has a first-class license, but he was wasting approximately 40 per cent of the fuel.

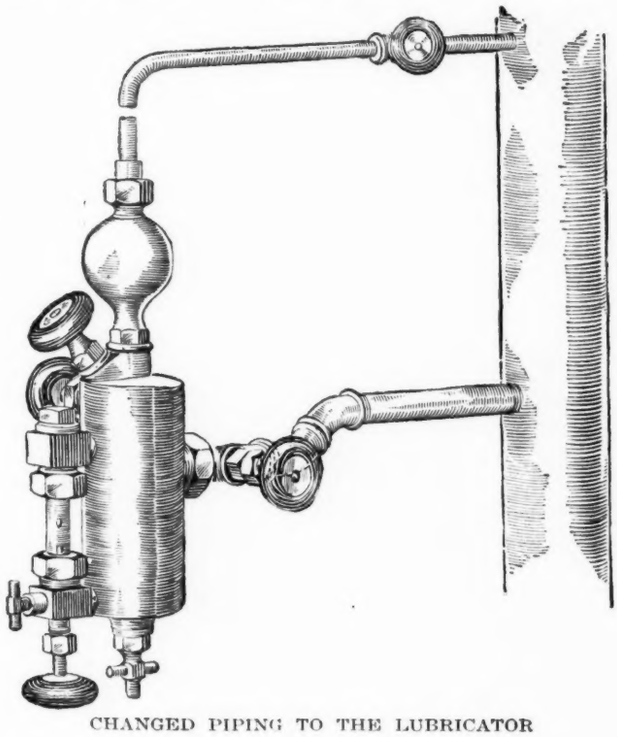
He could tell you how the engines and pumps were running and what trouble he had with his engineers and oilers, but when I asked about his boilers and what efficiency he was getting out of the fuel, he said that he got from 5 to 7 lb. of water per pound of coal, but that what was wanted at that plant was steam, as they had to keep going.

I say such men as this should not be allowed to operate power plants of any kind. If there were many like him, the employers would begin to think that engineers are not a very intelligent class of men. I hope the day is not far off when there will be a law to the effect that no person shall be allowed to operate a power plant until he has acquired a thorough technical and practical knowledge of combustion and power-plant efficiency, besides a good practical knowledge of machinery.

North Tonawanda, N. Y. C. J. MILLER.

Protecting Lubricator Gaskets

The following shows how trouble with lubricators was overcome. The illustration shows the connections that were used to prevent the top gasket of the sight-



CHANGED PIPING TO THE LUBRICATOR

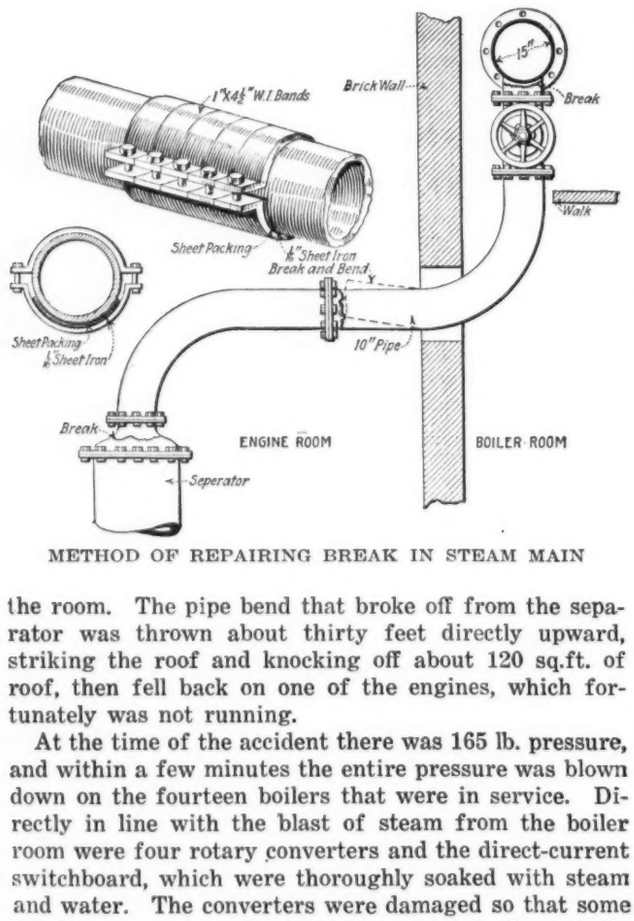
feed glass from softening and squeezing out on the stuffing nut. Instead of connecting the lubricator feed pipe direct to the steam pipe, as is the general practice, I used two 45-deg. elbows and a close nipple. This arrangement holds the condensation between the lubricator and the ell nearest the steam line and so prevents steam from coming in direct contact with the lubricator, thus preventing overheating of the top gaskets.

Brooklyn, N. Y. LEROY W. HAYWOOD.

Unusual Break in a Ten-Inch Steam Main

At five o'clock on the morning of March 15 a ten-inch pipe broke loose from the main header in the plant of the Union Traction Company of Indiana, at North Anderson, causing about $3,000 damages. Fortunately, no one was injured although there were five men in close proximity to the place of the accident. The sketch shown will give a good idea of the location of the piping and the nature of the break.

The exact cause of the accident will probably never be known, as the evidence submitted by the operating force leaves the matter in doubt. The watch engineer in charge, who was close by, reported that there was a loud explosion on the boiler-room side of the division wall and instantly the pipe broke away from the separator on the engine and broke out a part of the division wall, which allowed the full force of the steam to enter the engine room, driving all the operating force from



METHOD OF REPAIRING BREAK IN STEAM MAIN

the room. The pipe bend that broke off from the separator was thrown about thirty feet directly upward, striking the roof and knocking off about 120 sq.ft. of roof, then fell back on one of the engines, which fortunately was not running.

At the time of the accident there was 165 lb. pressure, and within a few minutes the entire pressure was blown down on the fourteen boilers that were in service. Directly in line with the blast of steam from the boiler room were four rotary converters and the direct-current switchboard, which were thoroughly soaked with steam and water. The converters were damaged so that some of them were out of commission for two days, badly crippling the through service between Indianapolis and Fort Wayne and Indianapolis and Marion.

There was considerable difficulty in getting the plant started again due to the fact that water was blown down in all the boilers except two. As the plant does not have city water connections, the start was made on these two boilers. There was a partial resumption of service six hours after the accident and a full resumption thirty-six hours afterward. The break being a nozzle directly off the main steam header caused the cutting off of service of five boilers and two engines until the header was patched, which was done by trimming the broken section and covering the hole with a piece of one-eighth inch sheet packing and a piece of one-sixteenth inch sheet iron held in place by five 2-piece, wrought-iron clamps made of 1 x 4½-in. bars, which made a perfectly tight job.

There were three breaks in connection with the accident, which probably happened in this order: First, the initial break probably occurred in the nozzle close to the header; second, when the break occurred at the header, the bend dropped about six inches, which broke off the connection at the top of the separator; third, when the section of pipe was blown upward, the third break occurred at the flange connection between the two bends. A new section of header consisting of steel pipe with welded nozzles and forged-steel flanges and Crane lap joints will replace the broken section of header. The old header is made up of cast-iron sections from six to eight feet long and has been in service for nearly twenty years. The construction of the header and the outlet connections to the engines is such that the vibrations due to the pulsations of steam to the engines would tend to set up a crystallization at the point where the break occurred. This is one theory that has been advanced as to the cause of the accident.

Distance of Bridge Wall from Boiler Shell

In my opinion Mr. Smythe is right (Feb. 24 issue) regarding the distance between the bridge wall and the boiler shell. The standard for boilers 50 to 60 in. in diameter is 9 in. and for boilers 61 to 72 in. in diameter is 10 in. between the bridge wall and the boiler shell. As the boilers in question are 78 in. in diameter, a distance of 11 in. would be about right.

At the city water works of Monticello, Ill., we have two 80-hp. boilers 60 in. in diameter, and the bridge wall is set 9 in. from the boilers. Very good service is given; in fact, we could not ask for any better. Our load is generally very light, but in case of fire we are required to crowd the boilers, and even then we get very good results.

I believe that in all cases the bridge wall should be of flat surface and not made to conform to the shape of the boiler. It is also a good plan to slope the front of the bridge wall 45 deg. toward the grates by stepping the grates up as they are laid and facing them with some kind of heat resisting material. W. A. PLIMPTON.

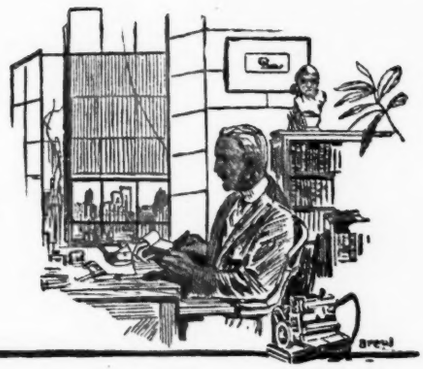
Monticello, Ill.

I had trouble with a marine boiler on a tugboat, in that I could not get it to steam. The captain claimed that the bridge wall should be the same distance from the boiler as the width of the ashpan. I claimed it should be a larger opening over the bridge wall than the area of the air space.

He had his way first, and we built the wall with a distance of 8 in. from the boiler. The boiler did not steam so well as before the change, so we made it 10 in. from the boiler, which gave better results. Then it was made with a distance of 12 in., and at this spacing the boiler steamed easily and was easy on fuel. Hoping to get still better results, the bridge wall was made with a 14-in. space, but conditions were worse, so the 12-in. space was adopted as that seemed to work the best.

Clear Creek, Canada. GEORGE A. MILLEN.

INQUIRIES OF GENERAL INTEREST



Advantages of Turbo-Air Compressors—What are the advantages of turbo-air compressors? A. W. L.

Compactness, adaptability to direct connection with high-speed steam turbines or electric motors and capability of yielding an output of compressed air free of oil or explosive hydrocarbon compounds that commonly result from cylinder lubrication of reciprocating air compressors.

Utilization of Discharge from Steam Kettles—How can we utilize the heat of exhaust from steam kettles? Our engine exhaust is insufficient for warming our buildings. Can we not combine the exhaust from the steam kettles with the engine exhaust? T. A. M.

When properly operated, the discharge from steam kettles should consist of only hot water formed by condensation of the steam used, and the most economical utilization of the heat remaining in the water would be to deliver it by a return trap to the boiler.

Lap and Negative Lead of Valve—What is the difference between lap and negative lead of a valve? W. P. S.

The term lap is used to signify the distance the admission edge of a valve overlaps the admission edge of its port when the valve is in the middle of its travel. Lead is the distance the admission edge of the valve has uncovered the admission edge of the port when the piston is at the beginning of a stroke from the same end of the cylinder, and negative lead is the distance the admission edge of the valve overlaps the admission edge of the port when the piston is at the beginning of a stroke from the same end of the cylinder.

Percentage of Fuel Energy Realized by Engine—An engine uses 25 lb. of steam per indicated horsepower-hour, and the evaporative economy of the boiler, under the operating conditions, is 8 lb. of water per pound of coal. Assuming that the heat value of the coal is 10,000 B.t.u. per pound, what percentage of energy contained in the coal is realized by the engine? R. L.

The fuel consumption would be $25 \div 8 = 3.125$ lb. of coal per horsepower-hour, and as 1 hp.-hr. $= 33{,}000 \times 60 = 1{,}980{,}000$ ft.-lb., there would be $1{,}980{,}000 \div 3.125 = 633{,}600$ ft.-lb. realized per pound of the coal. One B.t.u. is equal to 777.5 ft.-lb., and if the coal contains 10,000 B.t.u. per pound, the energy in a pound of the coal would be 7,775,000 ft.-lb., and the energy realized by the engine per pound of coal used would amount to $633{,}600 \times 100 \div 7{,}775{,}000 = 8.15$ per cent.

Setting Safety Cams of Corliss Engine—What is the method of setting the safety cams of a corliss valve gear? G. T.

When the cutoffs have been equalized, drop the governor to its lowest possible position and set the safety cams around to such a position that they will prevent the valves from being picked up, or at least, so each valve will be tripped before its lap is uncovered. Observe, however, that the safety cams are not set so far around that the valve cannot be picked up when the governor is resting on the starting pin or collar. Also place the governor in its highest position and see that the valves are not opened in that position, as that should be the condition to prevent the engine racing in case the load is suddenly removed.

Form of Pump Air Chambers—Why are pump air chambers made larger at the top than at the bottom? Do they give more cushioning effect than if they were merely the size at the bottom? E. M.

For easy passage of water in and out of the air chamber and prompter cushioning action of the air, the water connection with the air space should be no smaller than the pump outlet; but there is no advantage to cushioning effect by having the air chamber larger in diameter than the connection, except to afford sufficient volume of air space, and for that purpose any convenient proportions may be employed. Spherical, pear-shaped or cylindrical forms are most commonly employed, not because they produce any better cushioning effect, but because they meet the requirements of sufficiency of volume with compactness and economy of construction.

Regrinding Plug Cocks—What is the best method of grinding small brass plug cocks in place? Grinding the plug in its seat with a carpenter's brace has been tried with poor results. F. L. W.

When the plug is badly cut, it may have to be skimmed up in a lathe, or if the seat is badly cut, it will need reaming out with a tool that has the correct taper. For grinding, smear the plug with oil and fine emery or, better, use oil and pulverized glass. A better job of grinding is done by oscillating the plug by hand, occasionally turning it to a different position, each time cleaning off the plug and seat and applying a thin even coating of the grinding material. The operation is a tedious one, but is necessary for making a good job of grinding the plug and seat to good conical form. Grinding by turning the plug clear around, as with a brace, is likely to cause scoring of the surfaces.

Foaming and Priming of Boiler—What is foaming and what is priming of a boiler, and what is the danger of each? J. K.

A boiler is said to foam if the steam space is partially filled with unbroken bubbles of steam, and to prime if the steam carries water with it from the boiler. Foaming is caused by any materials either dissolved or suspended in the water which retard or interfere with the free separation of steam from the water. More generally, the trouble is caused by oily or dirty water and can be overcome by feeding and blowing. Where there is a surface blow, it can be used to good advantage. Priming may be caused by foaming or by particles of water being projected into the steam space by the action of boiling or activity of circulation of the water. When due to circulation, it can be reduced and sometimes stopped by checking the fire and carrying lower water level in the boiler. The dangers of foaming and priming are that the boiler-water level may become dangerously lowered from sudden opening of the safety valve or from water carried along with steam supplied for any purpose, and when carried over into an engine, the water is likely to cause a smash.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Steam-Turbine Economy Characteristics*

BY A. C. FLORY†

Characteristics common to the performance of modern commercial types of turbines. Willans total steam line, similar straight line relations of the total quantities of heat and the inlet pressure, and the constant-volume law are presented graphically to bring out the general principles governing turbine economy.

VARIATIONS in economy and performance of all types of turbines conform closely to certain simple rules or laws. The Willans Law, which states that the total steam passed per hour by a constant cutoff throttling engine when plotted as a function of the brake horsepower of the engine at constant speed will be a straight line, is fundamental. It has been found that this law, which was originally applied to the performance of constant cutoff engines regulated by throttling the steam supply, applies also to the performance of all types of steam turbines.

As shown in Fig. 1, the Willans total steam line is drawn from data of the estimated consumption of a 5,000-kw. turbo-alternator unit, the operating conditions being steam of 225-lb. gage pressure, 125 deg. F. of superheat; vacuum, 28.5 in.; speed, 1,800 r.p.m. In this diagram the Willans line extended indicates that the apparent total steam consumption at no load under the constant operating conditions set forth would be about 8,000 lb. per hour. If this no-load steam consumption is deducted from the total steam for various loads and the differences divided by the respective loads in kilowatt-hours, the result will be a constant amount of steam required for each kilowatt-hour produced, up to the bypass point, where the slope of the line changes. This is indicated on the diagram by a horizontal line marked "net steam per kw-hr., lb." If the no-load steam consumption per hour is divided by the load at any point, the quotient can be conventionally termed "friction steam per kilowatt-hour." The friction steam per kilowatt-hour added to the net steam per kilowatt-hour and plotted will produce the familiar curve showing the steam consumption per kilowatt-hour as a function of the load. Such a curve is shown in Fig. 1. This same result may be obtained more directly by dividing the total steam consumption by the load for different points on the Willans line. It can be seen that the Willans Law and its simple derivatives make a convenient and relatively simple method of showing graphically the performance of a machine and for checking the accuracy of a series of variable-load constant-speed tests made under approximately constant conditions.

It is also characteristic of turbine operation that the steam inlet pressure, after the steam has been reduced in pressure by the inlet regulating valve, when plotted as a function of the load, makes a straight line similar in form to the Willans total steam line. The inlet pressure—kilowatt line for a 5,000-kw. turbine having the same operating conditions as before—is shown in Fig. 2. This line forms a convenient check upon the accuracy of a series of tests, provided that the initial steam pressure, quality and vacuum are maintained approximately constant at all the loads at which the tests are made.

It has another important application in that it furnishes a convenient means of checking the internal condition of the turbine while it is in operation. If the inlet pressure-kilowatt line of a turbine is obtained when the unit is known to be in good condition and if, subsequently and while the machine is in operation, the inlet-pressure and kilowatt-load readings are plotted and compared with the original diagram, it is obvious that any change in the condition of the turbine will be revealed by a change in position or slope, or both, of the line. It is to be hoped that some such procedure will come into general use since its simplicity would not burden an operating engineer and because it has been found that in many plants there is a progressive accumulation of dirt or scale in turbine blading which ordinarily is not brought to the attention of the station operators until a large decrease in the load-carrying capacity of the unit results or until there is a serious accident to the machine.

Another characteristic common to steam machines which regulate by throttling the pressure of all the steam admitted to the turbine cylinder is known as the "constant-volume law," as it is based on the fact that, with such regulation, the cubic feet of steam per hour entering the turbine nozzle or inlet blading is approximately constant for all loads and initial steam conditions. This is illustrated by Fig. 3, in which are plotted data from tests on the same 5,000-kw. turbine showing the relation between the Willans total steam line, the specific-volume line and the constant-volume line. The specific-volume line represents the volume, in cubic feet per pound, of steam at the test inlet

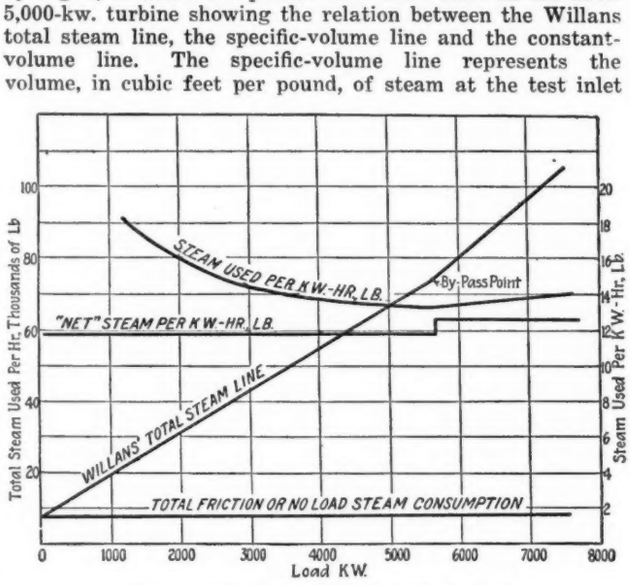


FIG. 1. WILLANS TOTAL STEAM LINE

pressure and quality (moisture or superheat). The constant-volume line is obtained from the products of the total steam per hour as taken from the Willans line and the calculated specific volume at the different loads as covered by the tests.

The constant-volume law has an important application in turbine work, as it furnishes a means for estimating the effect of changes in the initial steam conditions on the weight of steam that the turbine will pass per hour at constant speed. As an example, if it is known that a certain turbine will pass, without the bypass being open, 58,000 lb. of steam per hour with a pressure of 150 lb. gage and dry saturated steam, the total volume of steam passed per hour at the turbine inlet will be 58,000 lb. × 2.75 cu.ft. per lb. = 159,500 cu.ft. If the steam conditions are changed to 225 lb. gage and 125 deg. F. superheat, the weight of steam per hour which the machine will then pass without the bypass being open will be in inverse proportion to the ratio of the specific volumes of the steam at the two conditions, since the constant-volume law states that the total volume passed per hour at the blading inlet is constant. The specific volume of steam at 225 lb. gage and 125 deg. superheat being 2.335 cu.ft. per lb., the turbine would then pass (2.75 ÷ 2.335) × 58,000 = 68,300 lb. per hour, the bypass not being open. The example just given is conventional, as precisely the same machine would not be used for such a wide variation in initial steam conditions, but

*Abstract of paper read before the Technical League of the Employees' Mutual Benefit Association, Milwaukee.

†Manager, Steam Turbine Department, Allis-Chalmers Manufacturing Company.

the principle can be applied with accuracy in practice to smaller variations in steam conditions, and by combination with a knowledge of the effect of steam pressure and superheat on the economy of any particular turbine, forms a simple and convenient method of estimating the effect of changes in steam pressure and superheat on the maximum load that can be carried before the bypass opens.

With constant steam pressure, superheat and vacuum the energy available for work per pound of steam based on the Rankine Cycle is constant, and it is apparent in view of the Willans Law, that if the total B.t.u. available per hour are plotted as a function of the load there will result a straight line such as is shown in Fig. 4. This diagram is plotted from an estimate for a 5,000-kw. turbine. The characteristic form of the "total B.t.u. available per hour-kilowatt" line, forms an additional convenient check on the accuracy of any series of variable-load constant-speed tests below the bypass point and the "no load" or "friction" B.t.u. and the "net B.t.u. available per kilowatt-hour," which are derived from such plotted data and which are shown on the diagram, are of value in turbine-economy estimates.

The value of the net B.t.u. available per brake horsepower-hour (considering the turbine alone) has been found to be dependent only on the proportion of the blading of turbines which conform to a general design for a line of machines of various sizes (within certain limits) and for different operating conditions, and this value, therefore, the general rules given would have been more strictly correct, but for ordinary comparison and uses the convenience resulting from the use of the generator output as a load basis for plotting characteristic curves more than offsets the lack of accuracy.

In addition to those units of economy that have been plotted as a function of the load on the diagrams accompanying this article, the total heat consumption per hour and other measures of performance can be used if the object of the work being done makes it desirable. The simplicity of the Willans Law and the similar straight-line relation of the total quantities of heat and the inlet pressure afford an easy means of bringing to the attention of operating engineers the general principles governing turbine economy. In this connection it is well to point out that, in a multistage throttling turbine, the straight-line relation between the load and stage pressure is maintained at all stages as well as at the inlet or first stage. An understanding of such points would add to the efficiency of an operating engineer, as it would give him a clearer conception of the working of the machine he handles and enable him to better judge its internal condition by examining the operating records.

It will be noticed that certain of the diagrams have the bypass marked on them and that they indicate that the straight-line relation between the total quantities and the load is maintained for the condition resulting from admission of steam to an intermediate stage. This feature

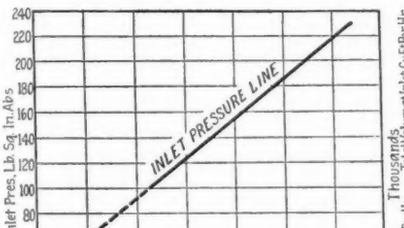


FIG. 2. INLET PRESSURE PLOTTED AS FUNCTION OF LOAD

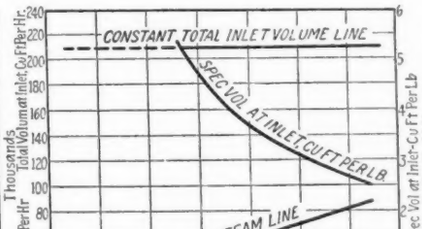

CONSTANT TOTAL INLET VOLUME LINE
SPEC VOL AT INLET CU FT PER LB
WILLANS TOTAL STEAM LINE
Thousands Total Volume at Inlet, Cu Ft Per Hr.
Total Steam, Lb Per Hr
Spec Vol at Inlet-Cu Ft Per Lb
Load KW

FIG. 3. RELATION BETWEEN WILLANS TOTAL STEAM LINE AND VOLUME LINES

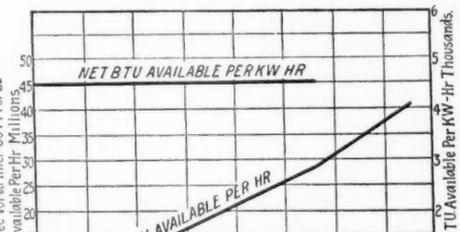

NET BTU AVAILABLE PER KW HR
TOTAL BTU AVAILABLE PER HR
NO LOAD OR FRICTION BTU
Total BTU Available Per Hr. Millions
Net BTU Available Per KW-Hr Thousands
Load KW

FIG. 4. TOTAL B.T.U. PLOTTED AS FUNCTION OF LOAD

is practically constant for different steam pressures, superheats, exhaust pressures and fractional loads. The values of the "no-load or friction B.t.u available," in the case of a similar line of turbines, are dependent on the sizes of the machines only (excepting large changes in the exhaust pressure), and for a certain size this value is, therefore, also constant for different operating conditions. With data from which a set of values for these two factors can be derived for a line of turbines, the estimating of the steam consumption of a machine at different loads and for specified operating conditions is a simple matter.

The regulation of a turbine by throttling introduces certain losses when the machine is operating at partial load, because of the effect of throttling on the B.t.u. available to the Rankine cycle. To illustrate the relative magnitude of this throttling-regulation loss at different loads for a 5,000-kw. 1,800 r.p.m. unit, the curve shown in Fig. 5 has been drawn. It is based on operating conditions of steam at 225 lb. gage, 125 deg. superheat and 28½ in. of vacuum. For convenience, the load is expressed in percentages of full load. The diagram shows the theoretical reduction in energy available to the turbine at the different fractional loads and is of particular interest because this loss is, in a measure, inherent in the necessary constant-speed regulation of all turbines.

The diagrams have all been based on the power output of the unit's generator, which introduces a variable factor due to the generator efficiency, being also a function of the load. If the brake horsepower of the turbine had been used as the basis for plotting the data, the application of has not been dwelt upon, as it is evident that with simple modifications the general principles given apply also for that part of the power output in excess of the bypass load.

In the discussion a number of points of interest came out. Relative to turbine design, selection of metals had to be made carefully with respect to the superheat in the steam. Even the finest gray cast iron grows if there is much superheat. The cause of this growth is not entirely the amount of superheat or the temperature that goes with it, but the temperature fluctuations encountered and the kind of iron used.

It was pointed out that the efficiency relative to the Rankine-cycle efficiency was obtained from the formula,

$$R = \frac{3{,}415}{\textit{B.t.u. available per lb. of steam} \times \textit{lb. of steam per kw.-hr.}}$$

3,415 being the old 2,547 B.t.u. (equivalent to 1 hp.hr.) divided by 0.746. This efficiency ranges from 50 per cent or less in a 300-kw. machine to almost 80 per cent in the large machines. In the large sizes the variation in efficiency is very slight from size to size as the curve becomes quite flat.

In reply to an inquiry as to whether the turbine and generator were set up and tested before shipment, it was stated that the unit is set up complete and overspeeded 10 per cent when running at no load. The overspeed safety stop is tripped three or four times. There is no advantage in running a turbine at load before being erected in its permanent location. The steam turbine itself, before connecting the generator, is overspeeded 25 per cent, producing 50 per cent excess stresses. It is important to get the

generator and turbine set up together before shipment. Final balancing of these units is largely a "cut-and-try" proposition. In balancing, the relative positions of the two elements are not changed

In modern turbine design, the governor does not usually open the bypass until the machine is working well up to capacity. The bypass is provided so that upon a drop of steam pressure or vacuum the machine will hang on to its load. This is more important in industrial plants than in central-station practice.

The fact was brought out that the deflection of the shaft of a modern turbine due to its weight, is so small that difficulties as to clearance do not develop from this cause. In designing, a careful attempt is made to keep the normal speed reasonably far away from the critical speed. Shaft deflection may result in not permitting the bearings to be fully effective, and so modern practice tends to shorten bearing lengths.

Mr. Mortimer, president of the North America Co., explained how the Willans diagram of Mr. Flory's paper,

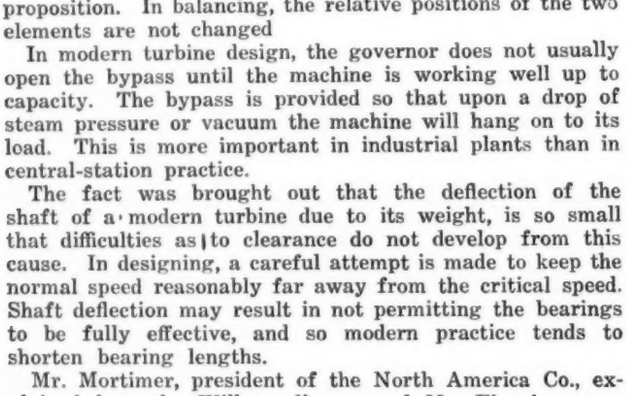


FIG. 5. THEORETICAL THROTTLING LOSS AT DIFFERENT LOADS

otherwise known as a "flow curve," had been used in a practical way in central-station practice by the Union Electric Light and Power Co. of St. Louis. In describing a method devised by him to more closely correlate efficient boiler capacity with the electric load, he emphasized the importance of the men in the turbine room knowing a half-hour in advance what load was to be carried and notifying the boiler room, so that the proper boiler capacity could be provided at the time required. In the Ashley Street Station, St. Louis, there are machines installed in 1908, 1909, 1911 and 1917. Only those of the same age and size would have the same steam economy. A chart was constructed on which were plotted "kilbers" against kilowatt load for each type of machine. A kilber is a unit expressing thousands of pounds of steam per hour. By referring to the load diagram of yesterday and to the corresponding day of last year, the load operator estimates the load that will be on the system one-half hour hence; decides what units shall be used to carry this load, refers to his diagram for the quantity of steam required; adds up the amounts for the total number of kilbers and signals to the boiler room a message "at 4:30, 15,000 kilbers will be required." The boiler-room foreman decides what boilers will be used to meet this requirement. It has been found that this assists materially in keeping the proper relation between boilers under steam and the load demand, and real economies have been thus effected. Correction is required if steam pressure or vacuum conditions do not remain constant.

The Board of Trade of Alberta, Can., has appointed a committee to investigate the possibilities of the waste coal from the mines in the generation of electricity in a large central plant and of proper distribution of this power to manufacturers and municipalities nearby. The fuel, which is very low in price, is being tested with a view to increasing its efficiency by pulverizing before it is utilized.

Reorganization Plan of the N. E. L. A.

Plans for the reorganization and expansion of the National Electric Light Association have been completed by M. H. Aylesworth, executive manager, and will be brought before the members at the convention in May for final approval.

A general survey by Mr. Aylesworth at the request of the National Executive Committee, upon the recommendation of President Ballard, resulted in the program of expansion in order to comply with demands for increased service in practical co-operation.

The work of the association, including appointment and direction of the headquarters staff, under supervision of president, vice presidents and National Executive Committee, will be performed by the executive manager. The organization at headquarters has been divided into five departments, under the direction of the executive manager and acting secretary. The rate-book and rate-research work, which formerly was carried on in Chicago, has been placed in charge of Fred W. Herbert, head of the Company Service Department. This department will dispense information and give to small and large companies alike the advantages of practical development demonstrations of the other company members.

A department of publicity under the direction of George F. Oxley has been formed, which will supervise the gathering and dissemination of all news, activities, etc., of the association.

Upon the recommendation of the Technical Section, approved by the National Executive Committee, an engineering department will immediately be formed. The duties of this department will include gathering statistics and formulating a program on the practical engineering problems that are affecting the industry at the present time.

A department dealing with committee activity has been formed and is under the direction of A. Jackson Marshall, committee secretary. The accounting department is in charge of the accounts of the association as well as the membership lists and the mailing of all material to members.

The reorganization plan calls for the division of the association into geographic divisions. The plan that has been proposed provides two methods of geographic division organization. Where strong state electrical associations or state public-utilities associations exist, the annual conventions and meetings may be held without regard to state boundaries, while other states will function through a geographic conference composed of delegates from the respective state associations. The purpose of geographic division organization is to decentralize where possible, the activities of the national association and harmonize the work of the state association, geographic division, and national association through co-ordination of all committee activities from the state association, through the geographic division and finally into the executive committees of the national association.

Little or no activity pertaining to the relation of the central station to the public has marked the work in the national association. A Public Relations National Section is to be formed, to overcome this deficiency.

Complete co-operation between all branches of the industry is the keynote of the reorganization plan, and every member company and its individual company will have a voice in the management of the association.

Exports of electrical machinery and appliances from the United States during February, 1920, show that batteries totaling in value $526,972 were shipped. Dynamos and generators valued at $363,340 and 3,140 fans valued at $79,780 were distributed throughout the world; incandescent lamps (carbon) valued at $9,746, and (metal) lamps with a total value of $363,391 were exported; magnetos, spark plugs, value, $251,876; motors, value, $381,203; telegraph apparatus, $16,750; transformers, $295,185; and miscellaneous electrical apparatus and appliances valued at $1,930,537 were exported.

Coal Production in Washington Decreased by the Miners' Strike

The coal produced in the State of Washington in 1919 amounted to 3,059,580 tons, which represents a decrease of over 25 per cent from the production of 1918. The major portion of this decrease is due to the national coal strike which closed the mines of the state from Nov. 1 to Dec. 15, according to the annual report of the state inspector of coal mines, James Bagley.

Mr. Bagley goes on to say that the increase in wages to miners in the last few years and the high cost of materials have prevented coal from displacing fuel oil to a great extent in spite of the constantly rising price of the latter. Coal from British Columbia has always been a factor in the Washington market, and Utah and Wyoming coal has recently been shipped in to a considerable extent. Also hydro-electric power has taken the place of coal-burning plants, especially on the railroads. The result of these factors is a gloomy outlook for the coal mines of Washington, as at present it seems probable that most of them will work only half the usual time during the coming summer months.

During 1919 Whatcom County alone showed an increase in production. This exception to the general rule was due to the operation of the Bellingham mine, which was under development most of the year.

The state's maximum production was reached in October, when 4,760 employees, working 26.3 days, produced 373,198 tons. This was due to the increased demand in anticipation of the big strike. The average value at the mine was $3.59 in 1919, as compared with $3.53 in 1918.

The coke output showed a decrease of about 55 per cent of the 1918 production. Of the 65,332 tons produced, almost 36,000 tons came from ovens at the mines at Carbonado, Fairfax and Wilkeson. The decrease is largely attributed to the lowered demand from the Tacoma smelter and to the fact that exports of coke to smelters in British Columbia have been steadily declining.

Sidelights on N. E. L. A. Convention

Visitors to the N. E. L. A. Convention at Pasadena, Cal., May 18-21, by special arrangements such as are not obtainable by the individual tourist, will be enabled to see every feature of southern California life within the shortest space of time and with the greatest possible convenience.

Arrangements have already been completed by W. L. Frost, chairman of the entertainment committee, for a trip to Santa Catalina Island, twenty-six miles from the mainland. The island is a famous objective for tourists and fisherman.

Not the least interesting event at the convention will be trips through various motion-picture studios, about sixty of which are located within easy riding distance of headquarters. The delegates will be given an opportunity of seeing "thrillers" in the making.

Excursions have been planned to all the famous beach resorts which extend for miles along the Pacific Coast.

Trips by trolley and automobile will be made through what is known as the "Orange Empire." The trees will be loaded with fruit at the time of the convention.

Mount Lowe, which stands a mile high on the summit of the Sierra Madre range is another trip easily taken from the Hotel Huntington. A cable railroad and a wonderful piece of electrical trolley construction are the means of reaching the summit.

John B. Miller, president of the Southern California Edison Co., has opened his beautiful home, "Hillside," and the wonderful grounds surrounding it. Delegates and their guests will be entertained at tea here Thursday afternoon, May 20 at 4 o'clock. The gardens of Hillside are said to be among the most beautiful in southern California.

Engineers and technical men who desire to visit the great hydro-electric properties of the power companies of the Southwest, will be provided with automobiles and guides for excursions into the mountains.

Convention of American Association of Engineers

The sixth annual convention of the American Association of Engineers will be held at the Planters Hotel in St. Louis, May 10 and 11. A number of interesting speakers have been secured, including M. O. Leighton, chairman of the National Service Committee of Engineering Council, who will deliver an address on "Getting Salaries for Public Service Engineers into Budgets"; Francis A. Kellor, vice chairman of the Inter-Racial Council of New York, will speak on "The Manpower Engineer—The Opportunity of Americanism" and Fred Lavis of the American International Corporation of New York, who will speak on "Opportunities for the Engineer."

Group meetings for draftsmen, federal engineers, mining engineers and railroad engineers will be held on the evening of the tenth, and problems peculiar to each group will be considered and a report made at the general business session on the following day.

A number of constitutional amendments will be brought before the members for approval, the changes including the passage of constitutional amendments by letter ballot and several amendments covering changes in entrance fees and annual dues.

A schedule for the regulation of salaries of engineers in municipal service has been prepared by a committee of the association, and will be placed before the members of the board of directors at their next meeting in St. Louis on May 9.

Washington State Coal Commission Holds Preliminary Meeting

N. D. Moore and D. F. Buckingham, the latter general manager of the Roslyn Fuel Co., representing the mine owners, and Robert S. Harlin, president, and Ernest Newsham, secretary, of District No. 10, United Mine Workers of America, representing the miners, are the first four members of the commission to adjust the wages and working conditions of coal miners in the State of Washington. These four are to appoint a fifth member. A preliminary meeting of the four commissioners was recently held in the offices of the Washington Coal Operators' Association in Seattle.

This commission was provided for in the Government plan developed after last winter's strike, the Washington State situation being one of those not covered in the general wage decision.

Piston Bursts—Kills Man

The bursting of a piston, while being heated, which had been taken from a locomotive of the Donora Southern R.R. to the blacksmith shop for repairs, instantly killed the blacksmith.

The accident was most peculiar. The piston had been taken out of a locomotive and required some repairs before it could be replaced. In order to take the rod out of the piston, it had to be heated, so it was taken to the blacksmith shop and put in the forge. In a short time the pressure in the hollow piston became so great that a large piece was driven out of the head, striking the blacksmith, who was standing several feet distant, and breaking his neck, almost instantly killing him.

Figures contained in the eleventh (1919) annual report of the Public Service Corporation of New Jersey show that the Public Service Electric Co. was called upon to supply power, which exceeded in volume the output of energy in 1918. It is estimated that during 1918 war industries consumed about 90 per cent of the commercial power load. When the war ceased this power was absorbed by other industrial activities. The day load of the 60-cycle service in the northern zone for 1919 ran as high as 126,000 kw., compared with a maximum of 109,000 kw. in 1918. In the southern zone the day load reached 24,000 kw., as against 22,000 kw. the year before.

Pennsylvania Electric Association Discusses Power Factor

How vitally important power factor has become in the operation of alternating-current power systems was very clearly reflected in the second meeting of the year held by the Western Geographic Section of the Pennsylvania Electric Association, in which approximately 200 members and guests participated. The meeting was held in the William Penn Hotel, Pittsburgh, April 21. Chairman E. C. Stone presided at both sessions, one being held in the morning and the other in the afternoon, with a luncheon served in the hotel at noon. In opening the morning session, Chairman Stone gave a general outline of the power-factor problem, in which he said in part:

Every reduction in the cost of producing and delivering electrical energy to the job opens up new fields for its utilization, thereby furthering the prosperity and development of the community through greater use of power. The proper solution of the power-factor problem means a further reduction in the cost of electrical energy. It is, therefore, a most vital problem. Consider the Duquesne Light Co.'s system for example. If the power factor of all connected equipment utilizing the company's service could be raised to unity, the entire electrical system, including generators, lines, substations and transformers, could be made to carry 35,000 kw. more load than it carries at the present time, and the only additional investment required to accomplish this would be for an increase in the capacity of turbines and boilers at the power plant to bring them up to the greater capacity of the electrical system.

The production and transmission of energy through an electrical circuit involves two functions: First, the delivery of the energy for utilization in lamps, motors, etc.; second, the supplying of the necessary excitation for maintaining the magnetic fields essential to the operation of transformers and motors, which constitute a large part of the utilizing equipment. The energy must obviously be supplied from the power plant. The excitation, or wattless current, however, may often be supplied more economically from a point nearer to the load, thereby raising the power factor and increasing the capacity of generators, lines and transformers. The engineer's problem thus becomes: First, the design of utilizing equipment that will operate at high power factor, as for example, the synchronous motor; second, where this cannot be done, the providing of power-factor corrective apparatus, such as the condenser, which will compensate for the low power factor of the utilizing equipment; third, the joint application of high power-factor equipment and power-factor corrective apparatus in such manner and at such points on the transmission and distribution system as will combine to make the most economical system possible, consistent with satisfactory operating conditions for the consumer.

Rates Should Encourage High Power Factor

The commercial problem of power factor involves the development of a rate schedule that will bring about the working out of the engineer's problem so that the community as a whole will obtain its supply of power at the minimum cost. This necessitates rate provisions which, first, will make it profitable to the power customer to utilize his power at the most economical power factor, and secondly, will differentiate between the power customer who corrects his power factor and the customer who does not, so that the former will not be obliged to carry any of the burden imposed by the latter.

One of the principal hindrances to the development of power-factor schedules has been the difficulty in measuring power factors in a manner that was sufficiently simple, economical and reliable to be used as a basis for billing. At the present time a joint committee of the A. I. E. E. and the N. E. L. A. is studying this problem with a view to defining power factor accurately so that manufacturers will be given a basis on which to design suitable metering equipment. In the meantime a number of prominent companies are making use of the method which employs a standard polyphase watt-hour meter specially connected to register the kilovolt-ampere-hours of wattless component, instead of the usual kilowatts of true energy. At the present moment it seems quite probable that this method will come into such extensive use.

Two papers were presented at the morning session: "Power Factor and Kilovolt-Ampere Measurements," by W. H. Pratt; and "Analysis of Power-Factor Conditions on a Large Central-Station System," by C. L. Rupert. Mr. Pratt outlined the various conditions under which power factor and kilovolt-amperes must be measured and described the methods of making these measurements. The speaker expressed the opinion that, in general, the different methods of measurement are satisfactory. He said that the most serious part of the problem is due to wave-form distortion. He described a new type of meter containing two elements connected together through a pawl-and-ratchet arrangement, that would measure kilovolt-amperes with only one per cent error, over a phase-displacement range of 44 deg., it being possible to select the 44-deg. range anywhere between 1 and 90 deg. displacement. Abstracts from both Mr. Pratt's and Mr. Rupert's papers will appear in later issues.

During the luncheon H. W. Diggs, chairman of the Four-Minute Speaker War Organization, and A. M. Lynn, president of the West Penn Power Co., delivered addresses. Mr. Diggs urged greater co-operation between the public-service utilities and the public. Co-operation is abroad in the land, said the speaker, and wherever it has been tried the outcome has been satisfactory. The man who said, "The public be damned," has gone out of business. This one statement has done more harm to public utilities than anything else. Public opinion is a powerful thing, the speaker said, and emphasized this point by calling attention to how public opinion had broken the steel-mill workers' strike, coal-miners' strike and was also breaking the railway strike.

Demand for Power Exceeds Supply

In discussing the various problems relative to central-station operation, A. M. Lynn, president of the West Penn Power Co., pointed out that the power companies today could sell more power than they could finance the necessary extensions for, consequently, one of the most difficult problems in the operation of utilities had become that of finance. Coal, said the speaker, that cost $2.95 per ton at the power plant during the war will probably cost at least $4.15 per ton when the coal and railway situation is adjusted. Mr. Lynn illustrated the great economies that had resulted from the interconnection of the various power systems by calling attention to a case where 5,000 hp. had been supplied from a company operating in central Pennsylvania to another company in central Virginia, but to do this it was necessary to transmit this power through three different systems.

At the afternoon technical session two papers were presented: "Induction and Synchronous Motors for Industrial Applications," by C. W. Drake; and "Power-Factor Correction," by Robert Treat. Mr. Drake gave a very careful analysis of the application of both types of alternating-current motors. He said that overloaded systems were the cause of increased interest in power-factor corrections, and laid stress on selecting the correct size of induction motors, pointing out that it was ordinarily possible to increase the power factor 5 to 10 per cent, and in exceptional cases 20 per cent, over what is obtained in general practice, simply by the proper selection of induction motors.

The relative costs of synchronous and induction motors were taken up by Mr. Treat in his paper and shown on a set of curves. An abstract of both papers will appear in a later issue.

During the discussion considerable difference of opinion was expressed regarding penalizing customers for low power factor. However, increasing the demand charge in proportion to the power factor when the customer failed to maintain the power factor above a given value, or else meter both the kilowatt-hours and the kilovolt-ampere-hours, billing the customer for both, were the two methods that apparently met with most favor. In addition to the demand charge, to compensate for reduced use of power equipment, some were of the opinion that something should be included in the rate to compensate for the increased losses.

It was felt by many that the burden of correcting for low power factor should be up to the consumer, since in most cases the trouble was due to underloaded motors, consequently the customer had within his control the means of maintaining a good power factor. To illustrate the effect of the small customer's load on the power factor of a system, attention was called to one case where, if the power factor of all the large customers' loads was increased to 87

per cent, it would improve the power factor of the system as a whole only about 3 per cent, or raise it from 70 to approximately 73 per cent.

In discussing the different types of corrective devices, it was acceded that in the case of poor voltage regulation the synchronous machine would tend to improve conditions where static condensers had the effect of making them worse. One case was mentioned where on the 2,200-volt side of the transformers, at the end of a long transmission line, the voltage dropped as low as 1,400 volts, and by a proper use of the synchronous machines, already on the system it was possible to maintain around 2,000 volts.

From a survey made of 23 companies only six of them did not penalize their customers for low power factor. A total of 15 penalized on a demand-charge basis, 6 penalized for power factors less than 80 per cent, and 5 for power factors less than 85 per cent. Only three of the companies discounted for good power factors.

In discussing the question of using rotary converters for power-factor correction, it was brought out that the load on the machine should not exceed the arithmetical sum of the active and reactive loads. That is, if the machine is operating under 80 per cent normal load it will be able to supply only 20 per cent reactive leading kilovolt-amperes to the alternating-current system, instead of 60 per cent for a synchronous motor.

N. E. L. A. Convention Program

The program of the National Electric Light Association for the forty-third annual convention to be held at Pasadena, Cal., May 18-22, has been completed and everything is now in readiness for the event. The headquarters of the convention is the Hotel Huntington, Pasadena, one of the largest and most modern hotels in southern California. It is located in the beautiful San Gabriel Valley, with the Sierra Madre Range and Mt. Wilson in the background.

The convention activities will be formally opened by Governor William D. Stephens of California, who will deliver the address of welcome to the members of the association. President Ballard will respond to the welcome on behalf of the organization. H. Aylesworth, executive manager, will next address the assembly with an outline of the comprehensive plan of reorganization which will be placed before the delegates for final approval.

General sessions will be held during the mornings and special sessions in the afternoon.

Franklin T. Griffith, of the Portland Light and Power Co., will read the report of the committee on Water Power Development. Following this, A. E. Silver, of the Electric Bond and Share Co., chairman of the Inductive Interference Committee, will read a report covering the work of that body. Frank M. Kerr, of the Mountain Power Co., of Butte, Mont., will present a paper on "Electrification of Steam Railroads." Other reports and speakers will be: "Electrical Resources of the Nation," by M. S. Sloane, of the Brooklyn Edison Co.; George B. Foster, of the Commonwealth Edison Co. of Chicago, chairman of the Electric Vehicle Section of the association, will deliver an address on "Development, Manufacture and Marketing of the Electrical Vehicle"; Zena W. Carter, secretary of the Material Handling Machinery Manufacturers' Association, of New York, will read a paper entitled "Electric Machinery for All Handling"; and the Committee on Public Information, of which John F. Gilchrist, of the Commonwealth Edison Co., of Chicago, is president, will give figures and facts showing the value of proper publicity of association activities.

During the first afternoon session of the convention on May 19, Nathaniel A. Carle, chief engineer of the Public Service Electric Co., of Newark, N. J., will read the report of the Prime Movers Committee, of which he is chairman, and during the second afternoon session on May 20, R. F. Schuchardt, of the Commonwealth Edison Company, of Chicago, will present the report of the Committee on Electrical Apparatus.

On Friday, May 21, at the afternoon session, James H. McGraw, president of the McGraw-Hill Co., Inc., will read a report of the Committee on Federal and Municipal Transportation.

The social and pleasure end of the convention has not been forgotten. Extensive plans for the entertainment of delegates have been made by the entertainment committee.

HOTEL HUNTINGTON, PASADENA, N. E. L. A. CONVENTION HEADQUARTERS

Included in this part of the program are numerous excursions to places of interest and beauty by automobile, trolley, boat and train. Everything possible has been done so that the visitors can make the most of their opportunities of viewing life in southern California.

Governing Boards of Founder Societies Meet in Chicago

Upon the invitation of the board of direction of the Western Society of Engineers the governing boards of the four Founder Societies met contemporaneously in Chicago on April 19 and 20. The Western Society has a plan to unite all engineers in Chicago into one all-embracing society for combined action in technical advancement, public affairs and the upbuilding of the profession. The primary reason back of the invitation was to give an opportunity for a discussion and a clear understanding of the inter-relations of the Western Society and the Chicago chapters of the Founder Societies, as well as the general plans for service. The opportunity for an interchange of ideas between the various representative bodies came at a luncheon on Tuesday. Business as usual and the problems confronting each society were taken up at individual meetings of the respective councils throughout the two days.

On Monday evening there was a joint engineering societies dinner at which the engineers of the community had an opportunity to meet and welcome to the city the visiting bodies from the four great national societies. A. Stuart Baldwin, past president of the Western Society of Engineers, was toastmaster and in his opening remarks referred to the four founder societies as the foundation on which all other engineering associations had been formed and pointed out the early tendency toward separation and division, each new society specializing in its own particular field. Recently, the pendulum had swung in the opposite direction. Engineers of the present day were drawing together. They realized that in union there is strength and that the maximum of service can result only through unison of effort and co-operation.

The toastmaster called in turn upon Arthur P. Davis, president of the American Society of Civil Engineers; Arthur Fletcher, representing the American Institute of Mining and Metallurgical Engineers; Fred J. Miller, president of the American Society of Mechanical Engineers, and

Calvert Townley, president of the American Institute of Electrical Engineers. Each in his own way spoke of the change that had come over the minds of men in the last five years, affecting their viewpoint and their feelings toward one another. To keep abreast of the times, it was recognized that all societies must broaden their fields and functions. Man can attain age by mere existence, but engineering societies must do something to keep alive. They should always stand ready to adopt new ideas.

It was conceded that there was need for more teamwork among engineers. To do effective work for the city, the state and the nation they should combine. There should be publicity to enlighten the public about engineers and their work so that confidence might be placed in their judgment. In rendering service to the public it was the thought that views expressed should be on the technical side of the question. In other words, the enginer should in a sense be an expert witness, not a politician. In co-operative public service they should not adopt the selfish aim of advancing themselves and the profession. Rather they should serve the public, do something for them, and the public in turn would reciprocate.

By joint activity there was expectation of dealing more effectively than ever before with public matters. There were one hundred thousand engineers in the country separated into several hundred organizations, each doing something in its own way. If they could be made to understand that no attempt was being made to interfere with their work and that they were requested to participate only in questions of public interest, they should be willing to coöperate and it was the consensus of opinion that they would.

As the closing event in a most enjoyable evening, enlivened by community singing and an orchestra, Dr. Theodore G. Soares, from the faculty of the University of Chicago, delivered an address on "Efficient Democracy." He impressed the audience with the need for the spiritual and the ideal as well as the practical. In the great undertakings of the day, there must be coöperation and more able direction than ever before. The problem of the day was not to find big things to do, but to find enough big men to do the work waiting for them. There was need for expert advice in questions of finance, education, engineering and for a more intelligent democracy to choose its experts. The public must find the men who are best capable to lead.

Personals

George L. Myers, who has been connected with the Pacific Power and Light Co., Portland, Ore., for several years, has been made assistant to the president.

Brent Wiley, formerly manager of the steel mill section, Westinghouse Electric and Manufacturing Co., has been appointed assistant to manager, industrial department. Mr. Wiley will assume charge of mill industries.

George M. Ogle has been appointed to take charge of the consulting engineering department of the Vulcan Iron Works, Inc., Jersey City, N. J. Mr. Ogle was formerly chief electrical engineer of the United States Shipping Board Emergency Fleet Corp.

Otto F. Stroman, formerly manager of the price section of the Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa., has been appointed assistant to the manager in the industrial department. Mr. Stroman's duties will include development of new apparatus, commercial activities, etc.

C. H. Kennedy, M. E., formerly New York district manager of the Kennedy Valve Manufacturing Co., has been appointed general sales manager, with headquarters at the plant, Elmira, N. Y. J. S. Hanlon, of the Boston office, will assume charge of the New York office, and G. W. Waters, formerly of the sales department of the New York office, will be the Boston representative.

Society Affairs

The American Society of Mechanical Engineers will hold its annual dinner at the Engineers' Club on May 25.

The American Society for Testing Materials will hold its annual meeting at Asbury Park, New Jersey, June 22-25.

The New York Section of the A. S. M. E. will meet at the Engineering Societies Building on May 11. "Symposium on Cost Accounting" will be the topic of the meeting.

The National Electric Light Association Executive Committee at a recent meeting, voted to change the name of the Technical and Hydro-Electric Section to the Technical Section.

A State Chapter of the A. S. E. is being considered by members of the profession in North Dakota. A meeting was held on April 23 for the formation of tentative plans of organization.

The American Society of Mechanical Engineers, New Haven Branch, Connecticut Section, will meet on May 12. The subject of the evening will be "Airplanes," by a speaker from the Ballaudet Corp.

The Society for the Promotion of Engineering Education, Pittsburgh, Pa., will hold its next meeting at the University of Michigan, Ann Arbor, June 29 to July 2. The keynote of the meeting will be co-operation.

The Canadian Association of Stationary Engineers will hold its thirty-first annual convention at Woodstock, Ontario, June 22-24. The annual exhibition of power equipment and supplies will be held in connection with the convention

The Michigan Central Railroad Section of the American Association of Engineers recently adopted a resolution offering the services of each of its members to the management of the railroad when strikes made it necessary.

The National Executive Committee of the N. E. L. A. has given final approval to proposed changes in the constitution of the association. The changes provide for reorganization at headquarters and changes in the form of organization.

The American Society of Civil Engineers has voted against the proposal to co-operate actively with other engineering societies in the formation of a broader organization to secure united action of the engineering and allied technical professions in matters of common interest.

The American Water Works Association will hold its fortieth annual convention at Montreal, Canada, June 21-24. The Windsor Hotel has been selected as headquarters. Afternoon and evening sessions will be held and a number of papers presented, covering water-supply problems.

An Illustrated Lecture will be given in the banquet hall of the Engineers' Club, 32 West 40th Street, Wednesday evening, May 5 at 8 o'clock, by H. F. J. Porter, M.E., Topic: "Mr. Cornelius Henry Delamater—The Businessman; Captain John Delamater—The Engineer."

The Taylor Society, the national organization for the promotion of scientific management in industry, will hold a meeting at Rochester, N. Y., May 6-8 under the auspices of the Industrial Management Council and the Manufacturers' Council of the Rochester Chamber of Commerce. The papers to be presented at the meeting will cover every phase of production, management and industrial relations, including sales promotion and office operations.

The North Central Geographic Division of the N. E. L. A. was organized April 13, at a conference of electrical men of Minnesota, North Dakota and South Dakota, in the Hotel Radisson, Minneapolis, Minn. A resolution was adopted, consolidating the South Dakota Electrical Association with the Minnesota State Electrical Association into the North Central Geographic Division, and officers were elected to serve until the first annual convention, which will be held at the Hotel Radisson, Minneapolis, June 16 and 17.

The American Institute of Electrical Engineers will hold its thirty-sixth annual convention at the Greenbrier Hotel, Sulphur Springs, W. Va., June 29 to July 2. The tentative program follows: Electrical Machinery Committee, Symposium on temperature conditions prevailing inside large alternating-current generators; Protective Devices Committee; Special Committee on Determination of Power Factor, preliminary report and papers; Electrical Machinery Committee, symposium on excitation. Miscellaneous Session: "Alternating-Current Commutator Motors," by J. I. Hull; "High-Tension Insulator Porcelain," by W. D. Peaslee, "Wattless Power and Magnetic Energy," by J. Stephian; "The Corona Voltmeter—II," by J. B. Whitehead and Mr. Ishiku.

Business Items

The Combustion Engineering Corp. has leased the property at 43-45-47 Broad St., New York City, and will soon begin operations on the construction of a modern ten-story structure, which it will occupy as soon as completed. The property was leased for $1,500,000.

The International General Electric Co. has secured a contract for the electrification of the Paulista Railway Co.'s lines betwen Jundiahy and Compinas, Brazil, a distance of 76 miles. The equipment to be supplied includes twelve locomotives, material for the transmission line and substation and a 2,000-volt overhead of the twin-catenary construction. The contract amounts to nearly $2,000,000.

Trade Catalogs

The Ric-Wil Co., manufacturers of heat insulating products, Cleveland, Ohio, has completed the publication of a new 16-page catalog describing in detail materials for pipes distributing hot liquids and vapors such as circulating of oil through underground pipes enclosed in heated conduit and distribution of low-pressure steam. A copy will be sent on request.

The American Steam Conveyor Corp. of New York and Chicago has ready for distribution a 24-page booklet entitled "The American Trolley Carrier." The booklet describes a one-man method of handling fuel by means of the apparatus manufactured by this company. A copy will be sent on request.

The De Laval Steam Turbine Co., Trenton, N. J., has ready for distribution a new 44-page catalog entitled "Centrifugal Pumps." The booklet describes and contains a number of illustrations of De Laval single- and multiple-stage centrifugal pumps and explains the use of pump-characteristic curves in adapting pumps to various services, the adaptation of centrifugal pumps to different types of drives, the information desired by the manufacturers in order to design a pump to suit given conditions, etc. Formulas and tables are given for calculating horsepower, efficiencies, the reading of venturi meters, friction in pipe lines etc. A copy of the catalog will be sent on request.

COAL PRICES

Prices of steam coals both anthracite and bituminous, f.o.b. mines, unless otherwise stated, are as follows:

ALANTIC SEABOARD

Anthracite—Coals supplying New York, Philadelphia and Boston:

	Mine
Pea	5.30
Buckwheat	$3.40@$3.75
Rice	2.75@ 3.25
Barley	2.25@ 2.50
Boiler	2.50

Bituminous—Steam sizes supplying New York, Philadelphia and Boston:

Latrobe	$4.25@$4.50
Connellsville coal	4.25@ 4.50
Cambrias and Somersets	4.35@ 5.15
Clearfields	4.00@ 4.75
Pocahontas	6.50@ 7.00
New River	6.50@ 7.00

BUFFALO

Bituminous—Prices f.o.b. Buffalo:

Pittsburgh slack	$6.00
Mine-run	6.25
Lump	6.25@ 6.50
Youghiogheny	6.75

CLEVELAND

Bituminous—Prices f.o.b. mines:

No. 6 slack	$3.25@$4.00
No. 8 slack	4.25
No. 8—1-in.	3.50@ 4.00
No. 6 mine-run	3.50@ 4.00
No. 8 mine-run	4.50
Pocahontas—Mine-run	3.25@ 4.00

ST. LOUIS

Anthracite—Probably not more than 20 per cent of the demand in this market can be supplied. Prices effective Apr. 1 were as follows:

	Williamson and Franklin Counties	Mt. Olive and Staunton	Standard
Mine-run	$2.65@2.80	$3.00@3.50	$3.00@ 3.50
Screenings	2.50@2.65	2.50@3.00	2.50@3.00
Lump		3.75@4.50	3.75@4.50

Williamson-Franklin rate to St. Louis is $1.10; Other rates 95c.

CHICAGO

Bituminous—Prices f.o.b. mines:

	Freight rate Chicago
Illinois	
Southern Illinois	
Franklin, Saline and Williamson Counties	
Mine-Run $3.00@$3.10	$1.55
Screenings 2.60@ 2.75	1.55
Central Illinois	
Springfield District	
Mine-Run $2.75@$3.00	$1.32
Screenings 2.50@ 2.60	1.32
Northern Illinois	
Mine-Run $3.50@$3.75	$1.24
Screenings 3.00@ 3.25	1.24
Indiana	
Clinton and Linton	
Fourth Vein	
Mine-Run $2.75@$2.90	$1.27
Screenings 2.50@ 2.65	1.27
Knox County Field	
Fifth Vein	
Mine-Run $2.75@$2.90	$1.37
Screenings 2.50@ 2.60	1.37
Brazil Block $4.25@$4.50	$1.27

New Construction

PROPOSED WORK

Mass., Boston—Fay, Spefford & Thorndike, Archts., 15 Beacon St., will soon award the contract for the construction of a 9 story, 130 x 193 ft. garage on Kneeland St. Power for heat and elevators will be installed in same. Total estimated cost, $750,000. Owner's name withheld.

Mass., Mattapan (Boston P. O.)—The Commonwealth of Massachusetts, 36 State House, Boston, will soon award the contract for the construction of a nurses' building, dormitory and dining room, etc., at the Boston State Hospital, here. A steam-heating system will be installed in same. Total estimated cost, $265,000. Kendall, Taylor & Co., 93 Federal St., Boston, Archts.

N. Y., Brooklyn—The Syndicate, 215 Montague St., plans to build a 150 x 154 ft. theatre on Grand and Keap Sts. A steam heating system will be installed in same. Total estimated cost, $500,000. Address W. A. Small.

N. Y., Buffalo—The Hotel Statler Co., Washington St., is having plans prepared for the construction of a 17 story hotel and theatre building on Franklin and Mohawk Sts., Delaware Ave. and Niagara Sq. A steam heating system will be installed in same. Total estimated cost, $5,500,000. George B. Post, 101 Park Ave., New York City, Archt.

N. Y., Fillmore—The Fillmore Electric Co. plans to construct a water power plant, here. The plant will develop 600 hp. at low water. Water wheels, dynamos and other power house equipment will be installed in same. W. L. Young, Pres.

N. Y., New York (Bronx Borough)—The Amer. Legion of the Bronx Council c/o Starrett & Van Vleck, Archts., 8 West 40th St., is having plans prepared for the construction of a 4 story, 100 x 200 ft. club house. A steam heating system will be intalled in same. Total estimated cost, $400,000.

N. Y., New York (Richmond Boro)—The Bd. Educ., 500 Park Ave., New York City received bids for the installation of heating and ventilating apparatus at P. S. 11, from Gillis & Geoghegan, 537 West Bway., $58,700; W. J. Olvany, 177 Christopher St., $59,962; D. J. Rice, 42nd St. and Lexington Ave., $62,690. All of New York City.

N. Y., New York—The Knickerbocker Hospital, 131st St. and Amsterdam Ave., is having plans prepared for the construction of an 8 story, 141 x 201 ft. hospital on Convent Ave. and 130th St. A steam heating system will be installed in same. Total estimated cost, $1,250,000. J. Oakman, 345 5th Ave., Archt. and Engr.

N. Y., New York—The State Bank, 363 Stone Ave., Brooklyn, is having plans prepared for the construction of an 8 story 25 x 100 ft. bank and office building at 349 West 34th St. A steam heating system will be installed in same. H. R. Mainzer, 105 West 40th St., Archt. and Engr.

N. Y., Ossining—Charles F. Rattigan, Supt. of Prisons, Capitol, Albany, will receive bids until May 18 for furnishing and installing pumping apparatus, including two 275 gal. per minute centrifugal pumps, two 25 hp. motors, pipe connections in pump house and reservoir, etc. at the Sing Sing Prison, here.

N. Y., Utica—The Bd. Educ. received bids for the installation of a heating system in the proposed school building in the 16th Ward to be known as the Horatio Seymour School, from the Mohawk Valley Heating Co., 302 Broad St., $43,982 to $63,510; W. T. Cantwell, 306 Bleecher St., $44,262 to $49,988; H. J. Brandeles, 435 Lafayette St., $50,909 to $75,255.

N. J., Hackensack—The Hackensack Hospital, 3rd St., is having plans prepared for the construction of a hospital building. A steam heating system will be installed in same. Total estimated cost, $750,000. Crow, Lewis & Wick, 200 5th Ave., New York City, Archts. and Engrs.

N. J., Jersey City—J. B. Hamilton, 173 Jewett Ave., is in the market for a 500 cu.ft. belt driven air compressor and a 150 hp., 440 volt, 3 phase, 60 cycle slip ring a.c. motor.

N. J., Kearny (Arlington P. O.)—The Bd. Educ. plans to build a 3 story high school. A steam heating system will be installed in same. Total estimated cost, $400,000. Guilbert & Betelle, 665 Broad St., Newark, Archts.

N. J., South River—The Bd. of Pub. Wks. and the Borough Council will receive bids until May 10 for the design, construction, delivery and erection of building, machinery and equipment for an addition to the Electric Generating Station. E. B. Hedden, Supt.

Pa., Wilkes-Barre—St. Mary's Catholic Church plans to build a 3 story, 80 x 250 ft. convent on South Washington St. A steam heating system will be installed in same. Total estimated cost, $500,000.

Md., Baltimore—The Johns Hopkins University, Homewood St., is having plans prepared for the construction of a 3 story college addition. A steam heating system will be installed in same. Total estimated cost, $300,000. Carrere & Hastings, 52 Vanderbilt Ave., New York City, Archts. and Engrs.

D. C., Washington—The U. S. Capitol Buildings and Grounds Office, received bids for installing a refrigeration system in the second wing of the U. S. Capitol, (1a) work complete, (1b) complete except refrigeration system, (1c) refrigeration system (2) work complete according to bidder's specification, (2b) same as 1b, according to bidder's specification, (2c) same as 1c, according to bidder's specification, from W. G. Cornell Co., 923 12th St., N. W., (1a) $236,730, (1b) $62,630, (1c) $174,900; York Mfg. Co., York, Pa., (1c) $273,725, (2c) $215,645; Carrier Eng. Corp., 39 Cortlandt St., New York City, (2a) $340,900 alternate $317,300 and $272,500, (2b) deduct $235,100.

N. C., Charlotte—Albert Kahn, Archt., Marquette Bldg., Detroit, will soon award the contract for the construction of a 6 story, 90 x 198 ft. service station on West Trade and Poplar Sts., for C. C. Coddington. Steam boilers, etc., will be installed in same. Total estimated cost, $300,000.

N. C., Kingston—Joe Dawson, Mayor, and the City Council, City Hall, will receive bids until May 11 for furnishing power plant equipment including one 1,500 kw., 1,875 kva. at 80% P.F. turbo generator unit, one surface condenser complete with dry vacuum and hot well pumps, one 25 kw. turbine driven exciter unit, two 25 kw., 6.6 amp. series street lighting transformers, two horizontal motor driven centrifugal circulating pumps, two 500 hp. 225 lb. horizontal water tube boilers, one 1,500 hp. open feed water heater, 2 superheaters, 2 underfeed mechanical stoker units complete, boiler feed pumps, 2 brick settings for boilers, etc.

S. C., Charleston—J. A. Wetmore, Supervising Archt., Treasury Dept., Wash., D. C., received bids for the construction of a lighting plant from John R. Proctor, Inc., 74 Cortlandt St., New York City, $23,988; Carleton Mace Eng. Co., 18 Tremont St., Boston, Mass., $35,056; G. E. Eng. Co., 22 Laight St., New York City, $46,340.

La., Monroe—The Monroe Light & Power Co. plans to rebuild plant recently destroyed by fire and will be in the market for new machinery.

O., Columbus—The city will soon award the contract for the construction of a pumping station for the Shepard main trunk sewer, and installation of equipment. Total estimated cost, $30,000.

O., Ironton—The Bd. Educ. is having plans prepared for the construction of a 2 story, 100 x 110 ft. high school. A steam heating system will be installed in same. Total estimated cost, $500,000. F. L. Packard, New Hayden Bldg., Columbus, Archt.

O., Ravenna—The McElrath Tire & Rubber Co., 1836 Euclid Ave., Cleveland, is having plans prepared for the construction of a 1 and 2 story, 100 x 300 ft. factory and a 30 x 50 ft. boiler house. One 150 hp. boiler will be installed in same. Total estimated cost, $150,000. P. J. McElrath, Pres. D. C. Smith, Lennox Bldg., Cleveland, Archt. H. M. Bixler, Akron, Engr.

Mich., Flint—Smith, Hinchman & Grylls, Archts. and Engrs., 710 Washington Arcade, will soon award the contract for the construction of a 3 story, 73 x 152 ft. sales building on East 5th St., for the Dort Sales Co. A steam heating system will be installed in same. Total estimated cost, $100,000.

Mich., Hillsdale—The Bd. of Pub. Wks., City Hall, will receive bids until May 21 for furnishing power plant equipment including 1 approximately 1,000 kw. steam turbo generator with condenser, one 400

hp. water tube boiler with stokers, one 1,500 gal per minute motor driven centrifugal pumping unit.

Ill., Chicago—Ernest A. Mayo. Archt., 53 West Jackson Blvd., will soon award the contract for the construction of a 1 and 2 story, 300 x 300 ft. factory on North Central and Grand Aves., for the Casey-Hudson Co., 361 East Ohio St. A steam heating system will be installed in same. Total estimated cost, $300,000.

Wis., Hartford—The Kissel Motor Car Co. is having plans prepared for the construction of a 1 story boiler plant. Three 300 hp. boilers, stokers, etc., will be installed in same. Cahill & Douglas, 217 West Water St., Milwaukee, Engrs.

Wis., Milwaukee—The School Bd., 10th and Prairie Sts., will soon award the contract for the construction of a 1 story, 22 x 40 ft boiler house at the Garfield School. Two boilers will be installed in same. Total estimated cost, $50,000. Van Ryn and De Gelleke, Caswell Block, Archts. and Engrs. Noted April 27.

Mo., Kansas City—Harlan & Harlan Machine Wks., 308 B'way, is in the market for two 250, two 350 and two 500 hp. water tubular boilers for 150 lb. working pressure.

Tex., Austin—The State Bd. of Control will receive bids until May 10 for the installation of a complete heating system in the asylum for the insane. C. H. Page & Bros., Engrs.

Okla., Paden—The city is having plans prepared for the construction of waterworks systen. including pumping station, 65,000 gal. tank and tower, etc. Total estimated cost, $65,000. H. G. Olmsted & Co., Oil Exch. Bldg., Oklahoma City, Engr.

Okla., Pryor—The city voted $35,000 bonds to improve the waterworks including purification plant, pumping station and high line. V. V. Long & Co., Oklahoma City, Engr.

Okla., Walters—The city voted $125,000 bonds to construct waterworks, sewers and electric light plant.

Utah, Brigham—The city plans to rebuild the present hydro-electric plant and increase the capacity to 1,500 hp., etc. Total estimated cost, $125,000. C. O. Raskelly, Engr.

Wash., Olympia — The State Capitol Comn. will soon award the contract for the construction of a power house. A steam heating system will be installed in same. Total estimated cost, $100,000. Wilder & White, 50 Church St., New York City, Archts. and Engrs. Noted March 30.

Cal., San Francisco—The Bd. of Pub. Wks. will soon award the contract for the construction of a 3 story school building on Pacific Ave. Contract for installation of heating system will be sublet. Total estimated cost, $204,000. John Reid, Jr., 1st Natl. Bank Bldg., Archt.

Cal., Victorville—The Mojave River Irrigation Dist. voted $5,000,000 bonds to purchase and complete Little Bear Dam of Arrowhead Reservoir and Power Co. power development and distributing system to serve 27,000 acres. F. E. Trask, Central Bldg., Los Angeles, Engr.

Ont., London—The Pub. Utilities Comn. plans to build a dam on the Thames River at Springdale and develop 1,000 hp. to help the electrical power situation. Hydraulic turbines, generators, electrical switch apparatus, transformers, circuit breakers, etc., will be installed in same. Total estimated cost, $300,000. E. V. Buchanan, Hydro Bldg., Engr.

Ont., Sarnia—S. B. Coon & Son, Archts., 36 Toronto St., Toronto, will receive bids until May 5 for the construction of a 3 story high school, for the Bd. Educ. A vacuum steam heating system with blower and ventilation system will be installed in same. Total estimated cost, $325,000. Melvern F. Thomas, 229 College St., Toronto, Engr.

Ont., Toronto—The United Hotels Ltd., King Edward Hotel, will soon award the contract for the construction of a 16 story hotel addition on King St., E. A vacuum steam heating system will be installed in same. Total estimated cost, $2,000,000. Harkness, Loudon & Hertzberg, Confederation Life Bldg., Engrs. Watt & Blackwell, 79 Adelaide St., E. and Senween & Johnson, Ellicott Sq., Buffalo, N. Y., Archts.

CONTRACTS AWARDED

Conn., Bristol—The city has awarded the contract for the construction of a 2 story grammar school on Burlington Ave., to the Triangle Constr. Co., 57 South B'way, Yonkers, N. Y. A steam heating system will be installed in same. Total estimated cost, $250,000.

Conn., Danielson—The Goodyear Cotton Mills, Inc., will build 2 story housing buildings. A steam heating system will be installed in same. Total estimated cost, $500,000. Work will be done by day labor.

Conn., Danielson—The Goodyear Tire & Rubber Co., East Market St., Akron, O., has awarded the contract for the construction of a 1, 2 and 4 story manufacturing plant, to the Hunkin Conkey Constr. Co., Century Bldg., Cleveland, O. A steam heating system will be installed in same. Total estimated cost, $3,500,000.

N. Y., Brooklyn—The Bd. Educ., 500 Park Ave., New York City, has awarded the contract for the installation of heating and ventilating apparatus in P. S. 182, to Daniel J. Rice, 405 Lexington Ave., New York City, at $153,380.

N. Y., Brooklyn—The Bd. Educ., 500 Park Ave., has awarded the contract for the installation of heating and ventilating apparatus in P. S. 20, to Gillis & Geoghegan, 537 West B'way, New York City. Estimated cost, $155,994.

N. Y., New York—The Beth Israel Hospital Association, Inc., 70 Jefferson St., has awarded the contract for the construction of a 12 story, 107 x 184 ft. hospital on Livingston Pl., between 16th and 17th Sts., to G. Richard Davis, 30 East 42nd St. A steam heating system will be installed in same. Total estimated cost, $1,750,000.

N. Y., New York—The Curb Holding Co., 44 Court St., Brooklyn, will build a 12 story, 134 x 135 ft. office building on Washington St. A steam heating system will be installed in same. Total estimated cost, $1,750,000. Work will be done by day labor.

N. Y., New York—The Heckscher Bldg. Corp., 50 East 42nd St., will build a 24 story, 100 x 162 ft. office building on 57th St. and 5th Ave. A steam heating system will be installed in same. Total estimated cost, $3,000,000. Work will be done by day labor.

N. Y., New York—Liggett Winchester & Ley, 19 West 44th St., has awarded the contract for the construction of a 25 story, 100 x 240 x 11 x 54 ft. office and store building on 57th St. and 8th Ave. to Fred T. Ley, 19 West 44th St. A steam heating system will be installed in same. Total estimated cost, $2,500,000.

N. J., Hoboken—The Bd. Educ. has awarded the contract for installing a heating system in the proposed school 2, to John Cooney, 210 North 4th St., Harrison, N. J., at $112,494.

Pa., Farrell—The Colona Trust Co., B'way, has awarded the contract for the construction of a bank building to the R. H. Howes Constr. Co., 105 West 49th St., New York City. A steam heating system will be installed in same. Total estimated cost, $300,000.

Pa., Philadelphia—The Children's Hospital, 18th and Fitzwater Sts., has awarded the contract for the construction of a 3 story, 57 x 82 ft. hospital addition, to the Roydhouse Arey, 112 North Broad St. A steam heating system and power house equipment will be installed in same. Total estimated cost, $100,000. Noted Feb. 2.

Penn., Reading—Dives, Pomeroy & Stewart have awarded the contract for the construction of a 7 story, 60 x 207 ft. department store addition on 6th and Penn Sts., to L. S. Focht & Sons, Baer Bldg. A steam heating system will be installed in same. Total estimated cost, $400,000.

Pa., Pittsburgh—The Peoples Ice Co. has awarded the contract for the construction of a 1 story, 55 x 237 ft. ice plant, to the W. T. Grange Constr. Co.

Md., Baltimore—The Maryland Casualty Co., Baltimore St. and Guilford Ave., has awarded the contract for the construction of a 3 story, 300 x 300 ft. administration building and other buildings including power house, etc., to the Arundel Corp., 1515 Fidelity Bldg., and for the installation of boilers, to The Erie City Iron Wks., Erie, Pa. Total estimated cost, $3,000,000. Noted April 13.

Md., Baltimore—Norton, Bird & Whitman, 501 5th Ave., New York City, will build a theatre building. A steam heating system will be installed in same. Total estimated cost, $300,000. Work will be done by day labor.

La., Shreveport—The Consolidated Sanatarium Co. has awarded the contract for the construction of a 5 story, 40 x 300 ft. hospital on Louisiana Ave., to Garson Bros. A steam heating system will be installed in same. Total estimated cost, $500,000.

O., Akron—H. Thomas c/o W. A. Swasey, Archt., 101 Park Ave., New York City, will build a theatre. A steam heating system will be installed in same. Total estimated cost, $250,000. Work will be done by day labor.

O., Cleveland—The Amer. Steel & Wire Co., Western Reserve Bldg., has awarded the contract for the construction of a 1 story, 50 x 138 ft. boiler house on Lakeside Ave., to the Amer. Bridge Co., Frick Bldg., Pittsburgh, Pa. Estimated cost, $150,000.

O., Cleveland—The Globe Wernicke Co., 128 East 4th St., has awarded the contract for the construction of a 6 story, 50 x 189 ft. commercial building at 2044 Euclid Ave., to the H. K. Ferguson Co., 6532 Euclid Ave. A steam heating system will be installed in same. Total estimated cost, $250,000.

Mich., Bay City—The Bigelow Cooper Co., Marquette Ave., has awarded the contract for the construction of a 1 story, 55 x 150 ft. dry kiln addition and a 40 x 40 ft. power house on Marquette Ave., to the Bay City Stone Co., 1704 Woodside Ave., at $50,000.

Mich., Northville—The Bd. of Health, 233 St. Antoine St., has awarded the contract for the construction of a group of buildings to be constructed at the proposed Detroit Municipal Tuberculosis Sanatarium, including a 1 story, 47 x 87 ft. power house and a 40 x 120 ft. laundry, to John Finn & Son, 2328 Woodward Ave., Detroit, at $1,460,800. Noted April 13.

Ill., Chicago—The MacDonald Machine Co., 3204 Shields Ave., has awarded the contract for the construction of a 1 story, 150 x 400 ft. machine shop at 7600 South Racine Ave., to J. J. Schworm, 1374 South La Salle St. A steam heating system will be installed in same. Total estimated cost, $250,000. The Austin Co., 208 South La Salle St., Archt. and Engr.

Wis., Oshkosh—The Diamond Match Co., 111 Bway., New York City, has awarded the contract for the construction of an 88 x 360 ft. block storage building, to the Hutter Constr. Co., 128-136 Western Ave., Fond du Lac. A steam heating system will be installed in same. Total estimated cost, $250,000.

Wis., Sheboygan—The Badger State Tanning Co., South Water St. and Maryland Ave., has awarded the contract for the construction of a 4 story, 105 x 342 ft. tannery, to the Westinghouse, Church, Kerr Co., Inc., 37 Wall St., New York City. A steam heating system and steam power will be installed in same. Total estimated cost, $750,000.

Ia., Rippey—A. E. Jensen, Secy. Bd. Educ., has awarded the contract for installing heating and plumbing systems in the proposed 2 story, 63 x 105 ft. school, to the Bailey Plumbing Co., 404 Grand Ave., Des Moines, at $22,547. Noted March 30.

Ia., Waterloo—The Waterloo Gas Engine Co., Miles St., has awarded the contract for the construction of a 3 story, 100 x 120 ft. factory, to George F. Scales, Lafayette Bldg. A steam heating system will be installed in same. Total estimated cost, $500,000.

Minn., Fairmont—The city has awarded the contract for the construction of a central heating plant, to Robb-Bain Eng. Co., 1414 16th Ave., North, Minneapolis. Estimated cost, $150,000.

Minn., Keewatin — The School Dist. 9, Itasca Co., has awarded the contract for the construction of a 2 story, 160 x 174 ft. high school, to J. M. and W. A. Elliott, Exch. Bldg., Minneapolis. A steam heating and mechanical ventilating system will be installed in same. Total estimated cost, $440,000.

N. D., McVille—The city has awarded the contract for the construction of a 125,000 gal. reservoir and the installation of 3 pumps, etc., to Gedney & Murphy, Fargo, at $60,355. Noted April 27.

Mo., Kansas City—The Kansas City Federal Reserve Bank has awarded the contract for the construction of a 16 story, 115 x 145 ft. bank and office building on Grand and 10th Sts., to the George A. Fuller Constr. Co., 175 5th Ave., New York City. A steam heating system will be installed in same. Total estimated cost, $3,605,000.

PRICES - MATERIALS - SUPPLIES

Electrical prices on following page are prices to the power plant by jobbers in the larger buying centers east of the Mississippi. Elsewhere the prices will be modified by increased freight charges and by local conditions.

POWER-PLANT SUPPLIES

HOSE—

	Fire
Underwriters' 2½-in.	78c. per ft.
Common, 2½-in.	35%

	Air		
	First Grade	Second Grade	Third Grade
¼-in. per ft.	$0.55	$0.35	$0.25

Steam—Discounts from List

First grade..... 25% Second grade.....35% Third grade....40%

RUBBER BELTING—The following discounts from list apply to transmission rubber and duck belting:

Competition..... 50–10% Best grade..... 25%
Standard..... 40%

LEATHER BELTING—Present discounts from list in fair quantities (½ doz. rolls):

Light Grade	Medium Grade	Heavy Grade
25%	20%	10–5%

RAWHIDE LACING { For cut, best grade, 25%, 2nd grade, 30%. / For laces in sides, best, 81c per sq. ft.; 2nd, 78c. / Semi-tanned: cut, 20%; sides, 83c per sq. ft.

PACKING—Prices per pound:

Rubber and duck for low-pressure steam	$1.00
Asbestos for high-pressure steam	1.70
Duck and rubber for piston packing	1.00
Flax, regular	1.20
Flax, waterproofed	1.70
Compressed asbestos sheet	.90
Wire insertion asbestos sheet	1.50
Rubber sheet	.50
Rubber sheet, wire insertion	.70
Rubber sheet, duck insertion	.50
Rubber sheet, cloth insertion	.30
Asbestos packing, twisted or braided and graphited, for valve stems and stuffing boxes	1.30
Asbestos wick, ½- and 1-lb. balls	.85

PIPE AND BOILER COVERING—Below are part of standard lists, with discounts.

PIPE COVERING		BLOCKS AND SHEETS	
Pipe Size	Standard List Per Lin.Ft.	Thickness	Price per Sq.Ft.
1-in.	$0.27	½-in.	$0.27
2-in.	.36	1 -in.	.30
6-in.	.80	1½-in.	.45
4-in.	.60	2 -in.	.60
3-in.	.45	2½-in.	.75
8-in.	1.10	3 -in.	.90
10-in.	1.30	3½-in.	1.05

85% magnesia high pressure..... List

For low-pressure heating and return lines { 4-ply..... 50% off / 3-ply..... 52% off / 2-ply..... 54% off

GREASES—Prices are as follows in the following cities in cents per pound for barrel lots:

	Cincinnati	Chicago	St. Louis	Birmingham	Denver
Cup	8½	6.6	6.7	8½	10.5
Fiber or sponge	8½	8.6	13	8½	13.75
Transmission	10	8.1	13	8½	12.5
Axle	...	4.8	4.75	4½	7.0
Gear	6½	6.1	7.5	8½	8.5
Car journal	12(gal.)	4.7	4.7	4½	9.0

COTTON WASTE—The following prices are in cents per pound:

	New York		Cleveland	Chicago
	Current	One Year Ago		
White	13.00	13.00	16.00	11.00 to 14.00
Colored mixed	9.00 to 12.00	9.00 to 12.00	12.00	9.50 to 12.00

WIPING CLOTHS—Jobbers' price per 1000 is as follows:

	13½ x 13½	13½ x 20½
Cleveland	$52.00	$58.00
Chicago	41.00	43.50

LINSEED OIL—These prices are per gallon:

	New York		Chicago	
	Current	One Year Ago	Current	One Year Ago
Raw in barrels (5 bbl. lots)	$1.87	$1.55	$2.05	$1.66
5-gal. cans	1.87*	1.70	2.30	1.86

*To this *oil* price must be added the cost of the cans (returnable), which is $2.25 for a case of six.

WHITE AND RED LEAD—Base price per pound:

	Red				White			
	Current		1 Year Ago		Current		1 Yr. Ago	
	Dry	In Oil	Dry	In Oil	Dry and In Oil		Dry and In Oil	
100-lb. keg	15.50	17.00	13.00	14.50	15.50		13.00	
25- and 50-lb. kegs	15.75	17.25	13.25	14.75	15.75		13.25	
12½-lb. keg	16.00	17.50	13.50	15.00	16.00		13.50	
1-lb. cans	18.50	20.00	15.00	16.50	15.00		15.00	
5-lb. cans	20.50	22.00	16.00	17.50	16.00		16.00	

500 lb. lots less 10% discount; 2000 lb. lots less 10–2½%.

RIVETS—The following quotations are allowed for fair-sized orders from warehouse:

	New York	Cleveland	Chicago
Steel ⅞ and smaller	30%	40%	45%
Tinned	30%	40%	45%

Boiler rivets, ¾, ⅞, 1 in. diameter by 2 in. to 5 in. sell as follows per 100 lb.:

New York....$6.00 Cleveland...$4.00 Chicago...$5.37 Pittsburgh...$4.72

Structual rivets, same sizes:

New York....$6.10 Cleveland...$4.10 Chicago...$5.47 Pittsburgh...$4.82

REFRACTORIES—Following prices are f. o. b. works, Pittsburgh district:

Chrome brick	net ton	$75–80 at Chester, Penn.
Chrome cement	net ton	45–50 at Chester, Penn.
Clay brick, 1st quality fireclay	net M.	45–50 at Clearfield, Penn.
Clay brick, 2nd quality	net M.	40–45 at Clearfield, Penn.
Magnesite, dead burned	net ton	50–55 at Chester, Penn.
Magnesite brick, 9 x 4½ x 2½ in.	net ton	80–85 at Chester, Penn.
Silica brick	net M.	50–55 at Mt. Union, Penn.

Standard size fire brick, 9 x 4½ x 2½ in. The second quality is $4 to $5 cheaper per 1000.

St. Louis—Fire Clay, $35 to $50.

Birmingham—Silica, $51–50 @ 55; fire clay, $45 @ 50; magnesite, $85; chrome, $85.

Chicago—Second quality, $25 per ton.

Denver—Silica, $18: fire clay, $12: magnesite, $57.50.

BABBITT METAL—Warehouse prices in cents per pound:

	New York		Cleveland		Chicago	
	Current	One Year Ago	Current	One Year Ago	Current	One Year Ago
Best grade	90.00	87.00	74.50	79.00	70.00	75.00
Commercial	50.00	42.00	21.50	18.00	15.00	15.00

SWEDISH (NORWAY) IRON—The average price per 100 lb., in ton lots, is:

	Current	One Year Ago
New York	$21–26	25.50–30.00
Cleveland	20.00	20.00
Chicago	16.50	16.50

In coils an advance of 50c. usually is charged.

Domestic iron (Swedish analysis) is selling at 12c. per lb.

SHEETS—Quotations are in cents per pound in various cities from warehouse; also the base quotations from mill:

	Large Mill Lots	New York			
Blue Annealed	Pittsburgh	Current	One Year Ago	Cleveland	Chicago
No. 10	3.55–6.00	7.12@8.30	4.57	7.30	6.02
No. 12	3.60–6.05	7.17@8.05	4.62	7.40	6.07
No. 14	3.65–6.10	7.22@8.10	4.67	7.45	6.12
No. 16	3.75–6.20	7.32@8.20	4.77	7.55	6.22
Black					
Nos. 18 and 20	4.15–6.30	8.50@9.50	5.30	7.95	6.80
Nos. 22 and 24	4.20–6.35	8.55@9.55	5.35	8.00	6.85
No. 26	4.25–6.40	8.60@9.60	5.40	8.05	6.90
No. 28	4.35–6.50	8.70@9.70	5.50	8.15	7.00
Galvanized					
No. 10	4.70–7.50	9.75@11.50	5.50	8.50	7.15
No. 12	4.80–7.60	9.85@11.60	5.55	8.60	7.20
No. 14	4.80–7.60	9.85@11.60	5.50	8.60	7.35
Nos. 18 and 20	5.10–7.90	10.10@11.85	5.90	8.90	7.65
Nos. 22 and 24	5.25–8.02	10.25@12.00	6.05	9.05	8.05
No. 26	5.40–8.20	10.40@12.15	6.20	9.20	8.20
No. 28	5.70–8.50	10.70@12.45	6.50	9.50	8.50

*For painted corrugated sheets add 30c. per 1000 lb. for 5 to 28 gage; 25c. for 19 to 24 gages; for galvanized corrugated sheets add 15c., all gages.

PIPE—The following discounts are for carload lots f. o. b. Pittsburgh; basing card of Jan. 1, 1919, for steel pipe and for iron pipe:

BUTT WELD

Steel			Iron		
Inches	Black	Galvanized	Inches	Black	Galvanized
⅛, ¼, and ⅜	50½%	24%	¼ to 1¼	30½%	23½%
½	54½%	40%			
¾ to 3	57½%	44%			

LAP WELD

2	50½%	35%	2	32½%	18½%
2½ to 6	53½%	41%	2½ to 6	34½%	21½%

BUTT WELD, EXTRA STRONG PLAIN ENDS

⅛, ¼ and ⅜	48½%	29%	¼ to 1¼	39½%	24½%
½	51½%	39%			
¾ to 1¼	50½%	43%			

LAP WELD, EXTRA STRONG PLAIN ENDS

2	48%	37%	2	33½%	20½%
2½ to 4	51%	49%	2½ to 4	35½%	23½%
4½ to 6	50%	39%	4½ to 6	34½%	22½%

Stock discounts in cities named are as follows:

	New York		Cleveland		Chicago	
	Black	Galvanized	Black	Galvanized	Black	Galvanized
⅛ to 3 in. steel butt welded	40%	24%	40%	31%	54%	40½%
2½ to 3 in. steel lap welded	35%	20%	42%	27%	50%	37½%

Malleable fittings. Class B and C, from New York stock sell at list + 23%. Cast iron, standard sizes, net.

BOILER TUBES—The following are the prices for carload lots, f. o. b. Pittsburgh:

Lap Welded Steel		Charcoal Iron	
3½ to 4½ in.	40½	3½ to 4½ in.	15½
2½ to 3¼ in.	30½	3 to 3¼ in.	1
2¼ in.	24	2½ to 2⅞ in.	+ 1
1¾ to 2 in.	19½	2 to 2¼ in.	+16
		1⅜ to 1¾ in.	+29

Standard Commercial Seamless—Cold Drawn or Hot Rolled

Per Net Ton		Per Net Ton	
1 in.	$327	1¼ in.	$207
1½ in.	267	2 to 2½ in.	177
1⅝ in.	257	2¼ to 3¼ in.	167
1¾ in.	207	4 in.	187
		4½ to 5 in.	207

These prices do not apply to special specifications for locomotive tubes nor to special specifications for tubes for the Navy Department, which will be subject to special negotiations.

ELECTRICAL SUPPLIES

ARMORED CABLE—

B. & S. Size	Two Cond. M Ft.	Three Cond. M Ft.	Two Cond. Lead M Ft.	Three Cond. Lead M Ft.
No. 14 solid	$104.00	$138.00	$164.00	$210.00
No. 12 solid	135.00	170.00	225.00	265.00
No. 10 solid	185.00	235.00	275.00	325.00
No. 8 stranded	285.00	375.00	520.00	500.00
No. 6 stranded	400.00	500.00	560.00	.....

From the above lists discounts are:

	Net List
Less than coil lots	10%
Coils to 1,000 ft.	15%
1,000 ft. and over	15%

BATTERIES, DRY—Regular No. 6 size red seal, Columbia, or Ever-Ready:

	Each, Net
Less than 12	$0.45
12 to 50	.38
50 to 125 (bbl.)	.35
125 (bbl.) or over	.32

CONDUITS, ELBOWS AND COUPLINGS—These prices are f. o. b. New York with 10-day discount of 5 per cent.

	Conduit		Elbows		Couplings	
Size, In.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.	Black 2,500 to 5,000 Lbs.	Galvanized 2,500 to 5,000 Lbs.
¼	$80.50	$85.59	$19.13	$20.27	$7.04	$7.46
⅜	106.51	113.51	25.17	26.67	10.07	10.67
1	157.59	167.79	37.25	39.47	13.09	13.37
1¼	213.11	227.01	48.46	50.26	18.30	18.98
1½	254.93	271.43	64.62	67.02	22.61	24.45
2	342.99	365.19	118.47	122.87	30.15	31.27
2½	542.30	377.40	193.86	200.00	43.08	44.68
3	709.16	755.06	511.96	536.16	64.62	67.02
3½	871.24	935.64	1,141.62	1,184.02	86.16	89.36
4	1,064.93	1,130.33	1,319.32	1,368.32	107.70	111.70
4½	1,240.79	1,318.99	1,997.83	2,072.03	161.55	167.55
5	1,445.96	1,534.76	2,773.27	2,866.27	177.70	184.30
6	1,875.84	1,991.04	3,446.40	3,574.40	258.48	268.08

Standard lengths rigid, 10 ft. Standard lengths flexible, ½ in., 100 ft. Standard lengths flexible, ¾ to 2 in., 50 ft.

CONDUIT NON-METALLIC, LOOM—

Size I. D., In.	Feet per Coil	List, Ft.	
¼	250	$0.05½	
⅜	250	.06	
½	250	.09	
¾	200	.12	
1	200	.15	Coils.....40% off
1¼	150	.18	Less coils, 25% off
1½	100	.25	
1¾	100	.33	
1½	Odd lengths	.40	
2	Odd lengths	55	

CUT-OUTS—Following are net prices each in standard-package quantities:

CUT-OUTS, PLUG

S. P. M. L.	$0.11	T. P. to D. P. S. B.	$0.24
D. P. M. L.	.11	T. P. to D. P. T. B.	.38
T. P. M. L.	.26	T. P. S. B.	.33
D. P. S. B.	.19	T. P. D. B.	.54
D. P. D. B.	.37		

CUT-OUTS, N. E. C. FUSE

	0-30 Amp.	31-60 Amp.	60-100 Amp.
D. P. M. L.	$0.33	$0.84	$1.68
T. P. M. L.	.48	1.20	2.40
D. P. S. B.	.42	1.05	.....
T. P. S. B.	.81	1.80	.....
D. P. D. B.	.78	2.10	.....
T. P. D. B.	1.35	3.60	.....
T. P. to D. P. D. B.	.90	2.52	.....

FLEXIBLE CORD—Price per 1,000 ft. in coils of 250 ft.:

No. 18 cotton twisted	$22.00
No. 16 cotton twisted	27.00
No. 18 cotton parallel	26.50
No. 16 cotton parallel	34.50
No. 18 cotton reinforced heavy	34.00
No. 16 cotton reinforced heavy	42.00
No. 18 cotton reinforced light	30.00
No. 16 cotton reinforced light	36.75
No. 18 cotton Canvasite cord	28.50
No. 16 cotton Canvasite cord	32.00

FUSES, ENCLOSED—

250-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.25
35-amp. to 60-amp.	100	.35
65-amp. to 100-amp.	50	.90
110-amp. to 200-amp.	25	2.00
225-amp. to 400-amp.	25	3.60
425-amp. to 600-amp.	10	5.50

600-Volt	Std. Pkg.	List
3 amp. to 30-amp.	100	$0.40
35-amp. to 60-amp.	100	.60
65-amp. to 100-amp.	50	1.50
110-amp. to 200-amp.	25	2.50
225-amp. to 400-amp.	25	5.50
450-amp. to 600-amp.	10	8.00

Discount: Less 1-5th standard package 30%
1-5th to standard package 40%
Standard package 52%

FUSE PLUGS, MICA CAP—

0-30 ampere, standard package	$0.75C
0-30 ampere, less than standard package	0.00C

LAMPS—Below are present quotations in less than standard package quantities.

Straight-Side Bulbs — Mazda B—				Pear-Shaped Bulbs — Mazda C—			
Watts	Plain	Frosted	No. in Package	Watts	Clear	Frosted	No. in Package
10	$0.35	$0.38	100	75	$0.70	$0.75	50
15	.35	.38	100	100	1.10	1.15	24
25	.35	.38	100	150	1.65	1.70	24
40	.35	.38	100	200	2.20	2.27	24
50	.35	.38	100	300	3.25	3.35	24
60	.40	.45	100	400	4.30	4.45	12
100	.85	.92	24	500	4.70	4.85	12
				750	6.50	6.75	8
				1,000	7.50	7.75	8

Standard quantities are subject to discount of 10% from list. Annual contracts ranging from $150 to $300,000 net allow a discount of 17 to 40% from list.

PLUGS, ATTACHMENT—

	Each
Hubbell porcelain No. 5406, standard package 250	$0.24
Hubbell composition No. 5467, standard package 50	.32
Benjamin swivel No. 903, standard package 250	.20
Hubbell current taps No. 5638, standard package 50	.40

RUBBER-COVERED COPPER WIRE—Per 1000 ft. in New York.

No.	Solid Single Braid	Solid Double Braid	Stranded, Double Braid	Duplex
14	$12.00	$16.00	$13.90	$28.50
12	13.25	15.70	18.05	30.70
10	18.30	21.00	23.85	41.50
8	25.54	28.60	32.70	56.77
6	.....	.....	51.40	.....
4	.....	.....	70.00	.....
2	.....	.....	101.80	.....
1	.....	.....	131.86	.....
0	.....	.....	160.00	.....
00	.....	.....	193.50	.....
000	.....	.....	235.20	.....
0000	.....	.....	288.60	.....

Prices per 1000 ft for Rubber-Covered Wire in Following Cities:

	Denver Single Braid	Denver Double Braid	Denver Duplex	Birmingham Single Braid	Birmingham Double Braid	Birmingham Duplex
14	$19.50	$24.00	$39.50	$12.23	.....	$33.60
10	28.92	33.12	65.52	24.00	.....	57.02
8	40.32	45.12	89.64	33.60	.....	75.94
6	63.84	69.24	.....	60.10	.....	.....
4	.....	97.86	.....	.....	$93.41	.....
2	.....	145.20	.....	.....	120.40	.....
1	.....	189.00	.....	.....	155.23	.....
0	.....	251.40	.....	.....	188.77	.....
00	.....	305.40	.....	.....	229.19	.....
000	.....	317.40	.....	.....	278.64	.....
0000	.....	451.20	.....	.....	338.41	.....

Pittsburg—23c. base; discount 50%. St. Louis—30c. base.

SOCKETS, BRASS SHELL—

½ In. or Pendant Cap			⅜ In. Cap		
Key Each	Keyless Each	Pull Each	Key Each	Keyless Each	Pull Each
$0.33	$0.30	$0.60	$0.39	$0.36	$0.66

Less 1-5th standard package +50%
1-5th to standard package +20%
Standard package —10%

WIRE, ANNUNCIATOR AND DAMPPROOF OFFICE—

No. 18 B. & S. regular spools (approx. 8 lb.)	55c. lb.
No. 18 B. & S. regular 1-lb. coils	56c. lb.

WIRING SUPPLIES—

Friction tape, ¾ in., less 100 lb. 60c. lb., 100 lb. lots	55c. lb.
Rubber tape, ¾ in., less 100 lb. 65c. lb., 100 lb. lots	60c. lb.
Wire solder, less 100 lb. 50c. lb., 100 lb. lots	46c. lb.
Soldering paste, 2 oz. cans Nokorode	$1.20 doz.

SWITCHES, KNIFE—

TYPE "C" NOT FUSIBLE

Size, Amp.	Single Pole, Each	Double Pole, Each	Three Pole, Each	Four Pole, Each
30	$0.42	$0.68	$1.02	$1.36
60	.74	1.22	1.84	2.44
100	1.50	2.50	3.76	5.00
200	2.70	4.50	6.76	9.00

TYPE "C" FUSIBLE, TOP OR BOTTOM

30	.70	1.06	1.60	2.12
60	1.18	1.80	2.70	3.60
100	2.38	3.66	5.50	7.30
200	4.40	6.76	10.14	13.50

Discounts:

Less than $10.00 list value	+25%
$10 to $25 list value	+10%
$25 to $50 list value	+5%
$50 to $200 list value	—10%
$200 list value or over	—15%